Mallard Pass
Solar Farm

Mallard Pass Solar Farm

Appendices to the Applicant's Response to Interested Parties' Deadline 2 Submissions

Deadline 3 (29th June 2023)

EN010127
EN010127/APP/9.29
Planning Act 2008
Infrastructure Planning (Examination Procedure) Rules 2010

Planning Act 2008

Infrastructure Planning
(Examination Procedure) Rules 2010

Mallard Pass Solar Farm

Development Consent Order 202[x]

9.29 Appendices to the Applicant's Response to Interested Parties' Deadline 2 Submissions

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Appendices

Appendix A Hambleton Solar Planning Appeal Decision

The Planning Inspectorate

Appeal Decision

Hearing held on 31 May 2023

Site visits made on 30 May and 1 June 2023

by Alison Partington BA (Hons) MA MRTPI

an Inspector appointed by the Secretary of State

Decision date: 27th June 2023

Appeal Ref: APP/G2713/W/23/3315877
Land south of Leeming Substation, west of the village of Scruton, bordering Fence Dike Lane, part of Low Street and Feltham Lane, DL7 0RG

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by Lightrock Power Ltd against the decision of Hambleton District Council.
- The application Ref 21/01362/FUL, dated 29 April 2021, was refused by notice dated 8 August 2022.
- The development proposed is the installation of a solar photovoltaic array/solar farm with associated infrastructure.

Decision

1. The appeal is allowed and planning permission is granted for the installation of a solar photovoltaic array/solar farm with associated infrastructure at land south of Leeming Substation, west of the village of Scruton, bordering Fence Dike Lane, part of Low Street and Feltham Lane, DL7 0RG in accordance with the terms of the application, Ref 21/01362/FUL, dated 29 April 2021, subject to the conditions set out in Annex A.

Application for costs

2. At the Hearing an application for costs was made by Lightrock Power Ltd against North Yorkshire Council. This application is the subject of a separate Decision.

Procedural Matters

3. On 1 April 2023 Hambleton District Council merged with other Councils in North Yorkshire to form North Yorkshire Council. However, the development plan for the area formally covered by the District Council remains in place until such time as it is revoked or replaced. I have determined the appeal on this basis.

4. The Parish Council has raised concerns that the author of the Agricultural Considerations Report produced for the appellant by Kernon Countryside Consultations has not provided a signed declaration as required for RICS Surveyors acting as an Expert Witness. As such, they state that little weight should be given to this evidence. However, the appeal is being determined by way of an informal hearing not a public inquiry and so participants are not called upon as "expert witnesses", and signed declarations are not required as they are in proofs of evidence submitted to an inquiry.

Main Issue

5. The main issue in the appeal is the effect of the proposed development on, and the potential loss of, agricultural land.

Reasons

6. The appeal site comprises a number of agricultural fields that are used for a mix of arable and pasture. A short distance to the north of the site lies Leeming Bar Substation which would provide a grid connection for the proposed solar farm via an existing underground cable.

Planning Policy Context

7. Policy S1 of the *Hambleton Local Plan (adopted February 2022)* (HLP) sets out a number of sustainable development principles. These include making efficient and effective use of land, protecting and enhancing the high quality natural and historic environment, and supporting development and infrastructure provisions that take available opportunities to mitigate and adapt to climate change.

8. Policy RM6 of the HLP supports renewable and low carbon energy installations where all potential adverse impacts are, or can be made, acceptable. Similarly, paragraph 158 of the *National Planning Policy Framework* (the Framework) also indicates that applications for renewable and low carbon development should be approved if the impacts are, or can be made, acceptable.

9. HLP Policy S5 indicates that development in the countryside will only be supported where it is in accordance with national planning policy or other policies in the HLP and would not harm the character, appearance and environmental qualities of the area. In addition, where significant development is demonstrated to be necessary, the loss of the best and most versatile (BMV) agricultural land should be avoided wherever possible. If the benefits of the development justify the loss, areas of the lowest grade available must be used except where other sustainability considerations outweigh agricultural land quality considerations.

10. The Written Ministerial Statement on solar energy (25 March 2015) indicates that the use of BMV for solar farms has to be justified by the most compelling evidence.

11. The *Planning Practice Guidance* (PPG) on Renewable and low carbon energy, which also dates from 2015, provides a list of planning considerations that relate to large scale ground mounted solar photovoltaic farms[1]. These include: encouraging the effective use of land by focussing such developments on previously developed and non-agricultural land provided it is not of high environmental value; and where a proposal involves greenfield land, whether (i) the proposed use of any agricultural land has been shown to be necessary and poorer quality land has been used in preference to higher quality land; and (ii) the proposal allows for continued agricultural use where applicable and/or encourages biodiversity improvements around arrays.

12. However, the Framework which has been updated on several occasions since 2015, makes no such requirement and only indicates where significant development of agricultural land is demonstrated to be necessary, areas of

[1] Paragraph ID:5-013-20150327

poorer quality land should be preferred to those of higher quality[2]. In addition, whilst the draft *National Policy Statement for Renewable Energy (EN-3) (March 2023)*, seeks to avoid the use of BMV land where possible, it also indicates that land type should not be a pre-dominating factor in determining the suitability of the site location. Whilst this is a draft and relates largely to proposals that form part of the National Infrastructure regime, it still gives an indication of the government's most recent thinking on this issue.

Agricultural Land Quality

13. The national Agricultural Land Classification map indicates that the site is Grade 2 land. However, as I heard at the hearing this is indicative of the type of land in the area rather than providing an assessment of any particular field. As a result, the appellant submitted an Agricultural Land Classification report (the Amet report). This indicates that the majority of the site is Grade 3b agricultural land with a small portion (5ha) being Grade 2. However, a similar report produced for the Council (the ADAS report) indicates that the majority of the land is Grade 2 with a small amount (5.85ha) being Grade 3b. Both reports find the principal limitation to agricultural use of the land is soil droughtiness. Whilst I note the concerns raised regarding the location of one of the appellant's trial pits, from what I heard at the hearing I consider that the methodology used for both assessments was appropriate.

14. An assessment of both the Amet and the ADAS reports on behalf of the appellant concluded that the difference in the classification of the land turns on whether or not there is the potential to alleviate the compacted layer that both surveys found generally occurs at a depth of around 30-50cm, (although in some places is deeper), by standard agricultural operations. This conclusion was not disputed by other parties.

15. The *Revised guidelines and criteria for grading the quality of agricultural land (MAFF 1988)* (MAFF guidelines) highlights that sandy soils readily form compacted layers if cultivated or traversed when wet. Where such damage can be corrected by normal soil management methods it indicates it does not affect the grading. However, it also states that where significant compaction occurs below 35cm it may be difficult or impossible to ameliorate practically or economically. Such compaction is therefore said to be a long-term limitation which is taken into account through reduced permeability and available water capacity in the wetness and droughtiness assessments.

16. The reports both indicate that the compaction layer occurs below 35cm. Mr Shepherd, a local farmer indicated at the hearing that this was far deeper than a traditional 'plough pan' which would form directly below the layer of the plough at around 20cm. He also indicated that, in his view, it would not be possible to carry out subsoiling to this depth. In addition, the appellant's evidence states that the farmer of West House Farm, whose land comprises the larger part of the appeal site, has tried subsoiling but found it did not benefit yields and was uneconomic to carry out.

17. There was significant evidence provided in support of the different land gradings, including information on yields and evidence on root growth, although the MAFF guidelines clearly states that yield maps are excluded from

[2] Footnote 58

determining agricultural grade. It was also disputed whether the compaction layer was likely to be a natural or man-made feature.

18. Nonetheless, irrespective of whether this compaction layer is a man-made or natural feature, given its depth, the advice from the MAFF guidelines which is supported by evidence from the farmers, is that both practically and economically it is not possible to ameliorate this compaction layer by normal soil management methods. As such, I consider it is a long term limiting factor that should be taken into account when considering the grading of the land. I therefore consider that the Amet report which takes the impact of the compaction layer into account provides a more reasonable assessment of the agricultural land quality. Given this I consider that the majority of the appeal site does not form BMV agricultural land.

Loss of agricultural land

19. However, even if it were considered to be BMV agricultural land, Policy S5 of the HLP does not prevent the use of such land but requires that the benefits need to justify its loss. Similarly, the national guidance outlined above does not prevent the use of such land.

20. The proposal would change the use of the land for a period of 40 years, which accords with the life expectancy of new panels. Whilst this is a significant period of time it is not permanent. Furthermore, during the operational period the land around the solar panels would be used for the grazing of sheep, with both farmers expecting to expand their current flocks. Given the height and angle of the proposed panels I consider grass will be able to grow under the panels satisfactorily as well as between the rows of panels, enabling such grazing to take place.

21. As a result, apart from the small areas used for the fixed infrastructure, the majority of the land would still be used for some agricultural purposes during the 40 year period the solar farm operated and it is the intention that it would be returned fully to agricultural land at the end. Moreover, I am satisfied from the evidence before me that resting the land from intensive agriculture would be likely to improve soil health by increasing the organic matter in the soil and improving soil structure and drainage, even if a return to arable farming would then start to reverse this improvement.

22. I note the concerns that the productivity and versatility of the land would be reduced. Nevertheless, the specific way agricultural land is used is not a matter that is subject to planning controls. As such, there would be nothing in planning terms to prevent the farmers using the fields that form the appeal site for the grazing of sheep at present or even leaving them fallow. Given this, the fact that the proposal would limit the ability to carry out any arable farming does not, in my opinion, mean that it results in the loss of agricultural land when it can still be used for other agricultural uses. Furthermore, current government schemes actually encourage farmers to take land out of production and put it to grass, meadows, or trees for carbon capture.

23. Various concerns were also raised regarding the potential impact, particularly of the construction phase, on soil quality. A condition requiring a Soil Resource Management Plan can ensure how and when construction work takes place so that damage to the soil is minimised. In addition, I consider that the advice in the *Construction Code of Practice for the Sustainable Use of Soils on*

Construction Sites (DEFRA 2009), does not mean that it is necessary to remove all the top soil on the site prior to any construction taking place. In my view this guidance relates to sites where soil would have to be removed as part of the construction process, rather than every construction site. This is borne out for example, by the advice regarding Soil Resource Plans in section 5.1 which says such plans should provide maps showing the areas where soil is to be stripped and where it is being left in-situ.

24. Whilst the panels will need to be cleaned on a periodic basis, the appellant indicated that this only requires the use of water, but in any case, this can be controlled by a condition to ensure it does not impact on soil quality.

25. As such, the proposal would not result in either the temporary or permanent loss of BMV land as the land would continue to be used for some agricultural purposes whilst also being used to produce solar energy. Nor would the proposal be detrimental to the soil quality, so a return to arable production at a later date would still be possible.

Food Security

26. Whilst the reason for refusal refers to the impact of the proposal on the nation's food security, the Council agreed in the Statement of Common Ground and at the hearing, that there are no national or local policies, guidance or strategies that relate to food security and production. The appellant highlighted numerous government documents that state, and statistics that show, that there is no food security problem in the country and that the level of food production is good, and none of this was disputed by the Council. This accords with the fact, noted above, that they are paying farmers to take land out of production and/or utilise less intensive production methods. Moreover, I note that the majority of crops grown on the appeal site at present are largely used for industrial purposes rather than supplying the food chain, whereas if it were to be used for grazing of sheep it would be contributing food for human consumption. As such, I am satisfied that the proposed use of the land would not be detrimental to the nation's food security.

Alternative Sites

27. I have not been provided with any evidence that indicates that there is any national or local policy requirement to carry out an assessment of alternative sites for solar farm developments. Nevertheless, the appellant provided a sequential assessment. This concluded that there were no sequential preferable sites in the area. Moreover, the Council have not put forward any brownfield or lower grade alternative sites.

28. It was suggested that the area of search in the assessment could have been wider and that it should have considered more than just the Leeming Bar substation. To this end the Parish Council drew my attention to some other appeal decisions where a more substantial catchment area was required. However, given the proposal is seeking to use the spare grid capacity at this sub-station, and bearing in mind the limited opportunities that currently exist for grid connections nationally, I consider it is, in this case, justified to only consider sites within an area that could also make use of this capacity, rather than capacity that may exist at other substations elsewhere. In addition, from the technical considerations set out by the appellant at the hearing regarding

how connections to the substation need to be made, I consider that the area of search utilised in the appellant's assessment is reasonable.

29. Whilst the levels of solar irradiance are higher in the south of England, given the government's requirement to significantly increase the amount of energy produced from solar power, which I outline in more detail below, I am not persuaded that solar developments should only take place further south in the country.

30. Overall, I consider that even if the proposal is considered to represent the loss of Grade 2 agricultural land, there are no alternative sites available on lower grade land.

Conclusion on main issue

31. Bringing all these points together, I consider that the majority of the appeal site does not form BMV agricultural land. So, to accord with the policies outlined above consideration needs to be given to whether it would harm the character and appearance of the area and if any adverse impacts can be made acceptable. I return to this below.

32. Moreover, even if it was BMV agricultural land, it would not result in the loss of this agricultural land and there are no lower grade alternative sites available, so subject to the above considerations its use would be justified.

Benefit arising from the provision of renewable energy

33. The proposal would have an installed capacity of 49.9MW, estimated to provide sufficient electricity to power around 10,800 homes. The site benefits from an immediate connection to the grid by way of an underground cable to the nearby substation.

34. In recent years both the Government and the local council have declared an Environmental and Climate Change Emergency. Various recent government publications have highlighted the need to significantly increase generation from onshore wind and solar energy production, as it seeks to ensure that by 2035 all our electricity will come from low carbon sources. To achieve this ambitious target, it is clear that considerable growth in large scale solar farms will be necessary and this cannot be achieved solely by the use of brownfield land or roof top installations. In addition, the Council, in seeking to be carbon neutral by 2034, identifies the need to look at viable solar /renewable energy as one of its actions, even if there may not be any quantifiable target for renewable energy production in the area. The proposed development would make a valuable contribution to achieving these local and national goals.

35. Concerns have been raised regarding the manufacturing of the panels and how "green" solar power is. Be that as it may, the government clearly identifies solar energy as a renewable form of energy and one in which they want to see significant growth. Nor is there any requirement for the energy produced to be "needed" or used "locally". Moreover, the efficiency of the panels has increased markedly in recent years.

36. The support in both national and local policy for renewable energy is caveated by the need for the impacts to be acceptable, or capable of being made so, nevertheless, the renewable energy benefit of the proposal must be accorded substantial weight.

Other Matters

37. The application was accompanied by a Landscape and Visual Appraisal which assessed the potential landscape and visual effects of the proposal, including the cumulative effects with other solar farms in the wider area. The Council concluded that the harmful impacts the proposal would create would be relatively localised and could be effectively mitigated. From the evidence before me and what I saw on my site visits, I see no reason to come to a different conclusion.

38. The proposal would include a variety of landscape and biodiversity measures including new and improved hedging, wildflower grass strips, areas of new woodland, and the provision of bird and bat boxes. In addition, ecological and wildlife corridors would be provided across the site, and the areas of woodland would still be accessible to wildlife. The biodiversity metric shows that the proposal would result in a substantial increase in biodiversity net gain in terms of habitat, hedgerow and river units. As such, the limited amount of existing hedging that would need to be removed for the accesses to the site would be more than adequately compensated for.

39. The site is a short distance from junction 51 of the A1M, and the route to the site from this junction is such that traffic to the site would pass a very small number of houses. Given this and the level of traffic generation predicted over the construction period, the impact on the local highway network or on the living conditions of residents would not be significant. Once operational traffic generation would be minimal.

40. Subject to a condition the Ministry of Defence have confirmed that they have no objection to the proposal and its potential effect on pilots using RAF Leeming. The Glint and Glare study also assessed the impact on road users, including the A684. From my own observations, I agree with the conclusion that due to the distance between the road and panels, their relative orientation and the existing and proposed vegetation there is unlikely to be an impact on drivers. Nonetheless, it is recommended that a site survey is undertaken once the proposed perimeter fencing is established to see if further mitigation is required. I consider that would be appropriate.

41. Leases Hall and its Ice House are both Grade II Listed Buildings. The appellant's Heritage Impact Assessment considered the changes to the setting of these as a result of the proposal. Due to the considerable intervening vegetation that already exists, it concluded that the proposal would not harm the setting of these heritage assets. From the evidence before me, and what I saw at my site visits, I agree that there would be no harm to the setting of these heritage assets.

42. There are a number of isolated dwellings in the vicinity, and to the east of the site lies the village of Scruton. The distance between these various properties and the closest panels, together with the existing and proposed intervening vegetation, means that the proposal would not unacceptably harm the living conditions of occupiers, in terms of noise and disturbance or glint and glare. Nor is there any compelling evidence to show that the noise during construction would be detrimental to any horses in the locality.

43. The appeal site is in Flood Zone 1 but due to its size a Flood Risk Assessment was produced. This considered all types of Flood Risk and concluded that there

was a negligible flood risk and no specific mitigation was required. Subject to a condition, the Lead Local Flood Authority had no objection to the proposal. In the absence of any substantive evidence to the contrary I see no reason to come to a different conclusion in this regard.

44. The Parish Council suggested that a Section 106 agreement should be provided to ensure the provision of a community fund for projects in Scruton, a new bridleway and a footpath from Scruton station to the bus stop on the A684. However, I am not persuaded that such contributions would meet the tests set out in the Framework and the CIL Regulations for planning obligations, as they would not be necessary to make the development acceptable in planning terms nor would they be directly related to the development.

45. I note that the Wensleydale Heritage Railway runs to the south of the site. Whilst tourism can rely considerably on the quality of the countryside, the effect on this has already been assessed above and found to be acceptable. I am not persuaded that the changes to the landscape in this case would lead to the loss of viability to the railway or any other existing tourism related business.

Planning Balance, Conclusion and Conditions

46. The Framework sets out a presumption in favour of sustainable development, and renewable energy development is central to achieving a sustainable future. The appeal scheme would make a valuable contribution to this. In addition, significant biodiversity enhancements would be achieved. The proposal would however be a significant development in the countryside and policy requires that any impacts are, or can be made, acceptable. The only adverse impact identified is a limited localised harm to the landscape character and visual impact. This impact can be effectively mitigated.

47. Moreover, although I have concluded the land is not BMV agricultural land, even if it was, the proposal would not result in the loss of the agricultural land and there are no suitable alternative sites on lower grade land.

48. Consequently, I consider the proposal would not have an unacceptable impact on, or result in the loss of, agricultural land and so it would accord with Policies RM6 and S5 of the HLP. As such, there would be no conflict with the sustainable development principles set out in Policy S1 of the HLP.

49. For the reasons set out above I conclude the appeal should be allowed.

50. The Council and the appellant agreed a set of potential conditions, and these were discussed at the hearing. I have considered these in the light of paragraph 56 of the Framework and have revised a number of them following the discussion at the hearing.

51. In addition to the standard implementation condition (condition 1), to provide certainty it is necessary to define the plans with which the scheme should accord (condition 2). Conditions 3, 4 and 5 are reasonable and necessary to limit the period of the permission and to ensure the site is decommissioned either at the end of the permission or when energy generation ceases.

52. In the interest of the character and appearance of the area condition 6 is necessary. For the same reason and in the interest of biodiversity, conditions

14 and 15 are required. Also, for biodiversity reasons, conditions 17, 18 and 19 are necessary.

53. To protect soil quality and so enable the reinstatement of its agricultural land quality, conditions 7, 8 and 20 are required. Conditions 9 and 10 are necessary for reasons of highway safety. For this reason, as well as to protect the living conditions of local residents, condition 16 is required. In the interest of aviation safety condition 13 is necessary.

54. Condition 11 is necessary to ensure sufficient access for the maintenance of the water mains, whilst condition 12 is required to ensure the site is properly drained. To protect and record any potential archaeological remains on the site, condition 21 is necessary.

55. Conditions 7, 16 and 21 are all pre-commencement conditions and need to be so because they relate to how the construction phase is carried out. Conditions 9 and 13 are also pre-commencement conditions. The former because it is necessary to ensure a safe access is provided for construction traffic before construction work begins and the latter because the Glint and Glare Plan could affect the design of the proposal. In accordance with Section 100ZA of the Town and Country Planning Act 1990, the appellant has provided written agreement to the pre-commencement conditions.

Alison Partington

INSPECTOR

APPEARANCES

FOR THE APPELLANT:

Paul Burrell BSc(Hons) DipUP MRTPI	Planning Director, Pegasus
Tony Kernon BSc(Hons) MRICS FBIAC	Kernon Countryside Consultants Ltd
James Fulton	Amet Property
Thea Osmund-Smith	Counsel
Chris Sowerbutts	Lightrock Power

FOR THE LOCAL PLANNING AUTHORITY:

Ian Nesbit	Senior Planning Officer, North Yorkshire Council
Ruth Metcalfe	ADAS

INTERESTED PARTIES:

Maurice Daley	Scruton Parish Council
Harry Shepherd	Scruton Solar Action Farm Group
Tim Chapman	Local Farmer

DOCUMENTS SUBMITTED AT THE HEARING

1. Copies of various of the submitted plans at A3
2. Location Plan and EIA Screening Opinion Decision for a potential Solar Farm at Cobshaw Lane, Langthorne.
3. Schedule of suggested conditions with comments submitted by the appellant
4. Copy of email sent on 9 April 2023 in response to the appeal notification by Mr T Chapman
5. Sequential Testing and Alternatives legal opinion submitted by the appellant.

Annex A
Conditions

1) The development hereby permitted shall begin not later than three years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans: Site Location Plan Planning Drawing 1a 4004-REP-037; Land Under the Applicants Control Planing Drawing 1b 4004-REP-038; Indicative Site Layout 4004-SCT-DR-PRE-0002 REV G; Typical PV Panel Section Planning Drawing 4 4004_SCT_P_0001; Inverter/Transformer Planning Drawing 5 4004_SCT_P_0002; 53ft Battery Container (HVAC on ground) Planning Drawing 6 4004_SCT_P_0003; 2MW Inverter Transformer skid (8m) Planning Drawing 7 4004_SCT_P_0004; Security Fencing and CCTV Planning Drawing 8 4004_SCT_P_0005; Security Gate Planning Drawing 9 4004_SCT_P_0006; Access Track Cross Section Planning Drawing 10 4004_SCT_P_0007; Container Storage Units Planning Drawing 11 4004_SCT_P_0008; Indicative Temporary Construction Compound Planning Drawing 12 4004_SCT_P_0009; Client Substation Planning Drawing 13 4004_SCT_P_0010; DNO Substation Planning Drawing 14 4004_SCT_P_00011; Landscape Mitigation Plan 4004-DR-LAN-101 REV D; Proposed Access Junction Visibility Splay Assessment 4004-DR-ALR-002a; and Fence Dike Lane Proposed Access Junction Visibility Splay Assessment 4004-DR-ALR-0003.

3) The permission hereby granted shall be limited to a period of 40 years from the date when electricity is first exported from the solar panels to the electricity network (the First Export Date). Written notification of the First Export Date shall be given to the local planning authority within 14 days of the event occurring.

4) Within 6 months of the cessation of the export of electrical power from the site, or within a period of 39 years and 6 months following the First Export Date, a Scheme for the decommissioning of the solar farm and its ancillary equipment, and how the land is to be restored, to include a programme for the completion of the decommissioning and restoration works, shall be submitted to the local planning authority for its written approval. The solar farm and its ancillary equipment shall be dismantled and removed from the site and the land restored in accordance with the approved scheme and timescales.

5) If the solar farm hereby permitted ceases to operate for a continuous period of 12 months, then a scheme for the decommissioning and removal of the solar farm and ancillary equipment, shall be submitted within 6 months of the end of the cessation period to the local planning authority for its written approval. The scheme shall make provision for the removal of the solar panels and associated above ground works approved under this permission. The scheme shall also include the management and timing of any works and a traffic management plan to address likely traffic impact issues during the decommissioning period, an environmental management plan to include details of measures to be taken during the decommissioning period to protect wildlife and habitats, and details of site restoration measures.

6) Prior to their erection on site details of the proposed materials and finish including colour of all solar panels, frames, ancillary buildings, equipment, and enclosures shall be submitted to, and approved in writing by, the local planning authority. Development shall be carried out in accordance with the approved details and be maintained as such for the lifetime of the development hereby permitted.

7) Prior to the commencement of each phase of development (Construction, Operational and Decommissioning), a Soil Management Plan shall be submitted to, and approved in writing by, the local planning authority. The plan shall include, but not be limited to details pertaining to careful soil management during each phase, including consideration of the appropriate time of year for soil handling, planting beneath the panels and return to the former land quality as indicated in the Agricultural Land Classification survey dated 8th December 2020 – Issue 2 carried out by Amet Property. The Management Plan shall adhere to the guidance set out in the following documents (or any subsequent replacement versions):

- Defra's Construction Code of Practice for the Sustainable Use of Soils on Construction Sites (September 2009); and.
- The British Society of Soil Science Working with Soil Guidance Note on Benefiting from Soil Management in Development and Construction.

The Soil Management Plan as so approved shall be implemented, and adhered to, for each phase of the development.

8) To ensure against soil compaction and overland flow route disruption during construction, the soil should be chisel ploughed or similar and it should be restored to a pre-construction condition immediately post construction, the date of which should be notified in writing to the local planning authority within 14 days of it occurring. For the first three years after the completion of the construction phase, every six months, inspections of the planting and soil must be carried out by a qualified soil scientist, to ensure adequate growth of the planting and that any compaction or channelisation of the soil can be identified and addressed. Any remedial work identified in the inspection should take place within 6 months of the date of the inspection.

9) No development shall take place until the details on the accesses to be provided to Low Street and Fence Dike Land have been submitted to, and approved in writing by, the local planning authority. Prior to the commencement of the development the site access on Low Street shall be constructed and prior to the First Export Date the access on Fence Dike Lane shall be constructed. Both accesses shall be provided in accordance with: the approved details; with Standard Detail number E20 Rev A; and the following requirements:

- any gates or barriers must be erected a minimum distance of 13m back from the edge of the carriageway of the existing highway and must not be able to swing over the existing highway.
- Provision to prevent surface water from the site discharging onto the existing highway have been constructed and maintained thereafter to prevent discharges.

The accesses shall be retained as such for the lifetime of the development hereby permitted.

10) Prior to the proposed accesses on Low Street or Fence Dike Lane being brought into use, the visibility splays shown on the following approved plans

- Proposed Access Junction Visibility Splay Assessment 4004-DR-ALR-002a and
- Fence Dike Lane Proposed Access Junction Visibility Splay Assessment 4004-DR-ALR-0003

shall have been provided. Once constructed the visibility splays must be maintained clear of any obstruction and retained for that purpose at all times.

11) No building or other obstruction including landscape features and tree planting shall be located over or within five metres either side of the centre line of both public water mains that cross the site i.e. a protected strip width of ten metres. If the required stand-off distances are to be achieved via diversion or closure of the water main(s), the developer shall submit evidence in writing to the local planning authority that the diversion or closure has been agreed with the relevant statutory undertaker and that prior to construction in the affected area, the approved works have been undertaken.

12) The development hereby approved shall not be brought into use until the surface water drainage arrangements have been provided in full, in accordance with details which shall previously have been submitted to, and approved in writing by, the local planning authority. The approved measures shall be retained for the lifetime of the development.

13) No development shall take place until a Glint & Glare Management Plan (GGMP) has been submitted to, and approved in writing by, the local planning authority. The submitted GGMP shall contain, but not be limited to:

- detailed design, to include specifications of both solar panel (surface types, anti reflective coating), mounting systems, illustrated with sectional plans as appropriate to show the angle of elevation and angle of azimuth of each solar panel in the development.
- a schedule to regularly check and maintain the alignment of the solar panels;
- a protocol through which glint and glare complaints can be submitted, investigated, and any issues rectified/ addressed/ mitigated to include procedures to ensure that any mitigation needed is implemented following MOD consultation and agreement only;
- procedures through which complaints, associated actions/outcomes will be recorded/communicated and made available to the MOD on request;
- provision to urgently address any incidents of a major impact that may occur that restricts aviation operations at RAF Leeming to

apply interim measures that will stop the source of glint or glare until measures to provide an enduring mitigation can be implemented; and

- timescales for completing investigations, implementing remedial works and the provision of interim and, or enduring mitigations to address any impact.

The provisions set out in the GGMP and any modifications/mitigation, as agreed in writing with the local planning authority shall be maintained for the life of the development.

14) The development hereby approved shall be implemented in accordance with the management measures set out in the Landscape and Biodiversity Management Plan prepared by Arcus Consultancy Services dated April 2021.

15) Notwithstanding the previously submitted details, prior to the erection of the solar panels, a landscaping scheme shall be submitted to, and approved in writing by, the local planning authority. The submitted scheme shall include, but is not limited to:

- details of the species;
- numbers and locations of planting;
- timescales for implementation; and
- a Management and Maintenance plan covering the life of the development.

The landscaping of the site shall take place in accordance with the approved details and implementation programme. The site shall be maintained in accordance with the approved Management and Maintenance Plan for the life of the development hereby approved, and any planting which within a period of five years of planting dies, are removed or become seriously damaged or diseased shall be replaced in the next planting season with others of a similar size and species.

16) No development shall commence until a Construction Management Plan has been submitted to, and approved in writing by, the local planning authority. The plan shall include but not be limited to:

- Details relating to traffic management including measures to enable vehicles to enter and leave the site in a forward gear;
- Hours of operation and hours during which construction and delivery traffic will travel to and from the site; and
- Measures that will be implemented to minimise the creation and impact of noise, vibration and dust resulting from the site preparation, groundwork and construction phases of the development.

The Construction Management Plan as so approved shall be adhered to throughout the construction period.

17) The development hereby approved shall be implemented in accordance with the recommendations contained within paragraph 5.3.1 of the Ecological Impact Assessment prepared by Arcus Consultancy Services dated April 2021.

18) No external lighting shall be installed other than in complete accordance with a scheme that has previously been submitted to, and approved in writing by, the local planning authority. Any external lighting so installed shall thereafter be maintained in accordance with the approved details for the lifetime of the development.

19) Prior to the First Export Date the Biodiversity enhancements shown on the Landscape Mitigation Plan 4004-DR-LAN-101 REV D, and the mitigation and enhancement measures detailed within section 5.4 of the Ecological Impact Assessment prepared by Arcus Consultancy Services dated April 2021 shall be implemented and retained as such for the lifetime of the development hereby approved.

20) Prior to the First Export Date details of the cleaning procedure for the panels shall be submitted to, and approved in writing by, the local planning authority. The details shall include but not be limited to the frequency of cleaning, volumes of water required, details of any detergents to be used and any required mitigation. The cleaning of the panels shall thereafter take place in accordance with the approved details.

21) No development shall take place until a written scheme of investigation (WSI) has been submitted to, and approved in writing by, the local planning authority. The WSI shall include:

- the statement of significance and research objectives;
- the programme and methodology of site investigation and recording and the nomination of a competent person(s) or organisation to undertake the agreed works; and
- the programme (including timescales) for post-investigation assessment and subsequent analysis, publication & dissemination and deposition of resulting material.

The written scheme of investigation will need to be prepared and implemented by a suitably qualified professionally accredited archaeological practice.

No development shall take place until the site investigations and post investigation assessment has been undertaken in accordance with the agreed programme and details.

Appendix B NMU Provision in the Locality Drawings

Z:\7863_NSIP_SOLAR_FARM_CONFIDENTIAL\8GIS\PROJECTS\LVIA\7863_000_LVIA_LOCAL_WALKING_ROUTES_V2.MXD

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER

EN010127

LEGEND

- Order Limits
- Solar PV Site Area
- Open Access Land
- Macmillan Way Long Distance Path

Public Rights of Way

- Footpath
- Bridleway
- Byway open to all traffic
- Restricted Byway

Local Walking Routes

- Will's Walk: Stamford, Tolethorpe, Ryhall and Belmesthorpe (10.4km)
- Will's Walk: Pickworth and The Drift (6.7km)
- Will's Walk: Ryhall, Tolethorpe and The Drift (8.1km)
- Will's Walk: The Witham Five (12.6km)
- Will's Walk: Stamford and Uffington (10.7km)
- Will's Walk: Braceborough, Greatford and Shillingthorpe (5.1km)
- Will's Walk: Wilsthorpe and Braceborough (3.5km)
- Will's Walk: Little Casterton and Tolethorpe (3.6km)
- Will's Walk: Carlby and The West Glen River (3.3km)
- Ryhall Walk Number 2 (6.1km)
- Ryhall Walk Number 1 (6.6km)

Viewpoints

- Viewpoint F
- Illustrative Viewpoint
- Representative Viewpoint

Mallard Pass Solar Farm

PROJECT TITLE

MALLARD PASS SOLAR FARM

DRAWING TITLE

Access, PRoW & Local Walking Routes

Local Walking Routes	Total Distance (km)	Distance adjacent to Solar PV Site (km)	% of route affected
Will's Walk: Carlby and The West Glen River	3.3	0	0
Will's Walk: Little Casterton and Tolethorpe	3.6	0	0
Will's Walk: Wilsthorpe and Braceborough	3.5	0	0
Will's Walk: Ryhall, Tolethorpe and The Drift	8.1	0	0
Will's Walk: Stamford, Tolethorpe, Ryhall and Belmesthorpe	10.4	0	0
Ryhall Walk Number 2	6.1	0	0
Will's Walk: The Witham Five	12.6	0	0
Will's Walk: Braceborough, Greatford and Shillingthorpe	5.1	0	0
Will's Walk: Stamford and Uffington	10.7	0.4228	0.40%
Will's Walk: Pickworth and The Drift	6.7	0.5426	8.10%
Ryhall Walk Number 1	6.6	2.1378	32.40%

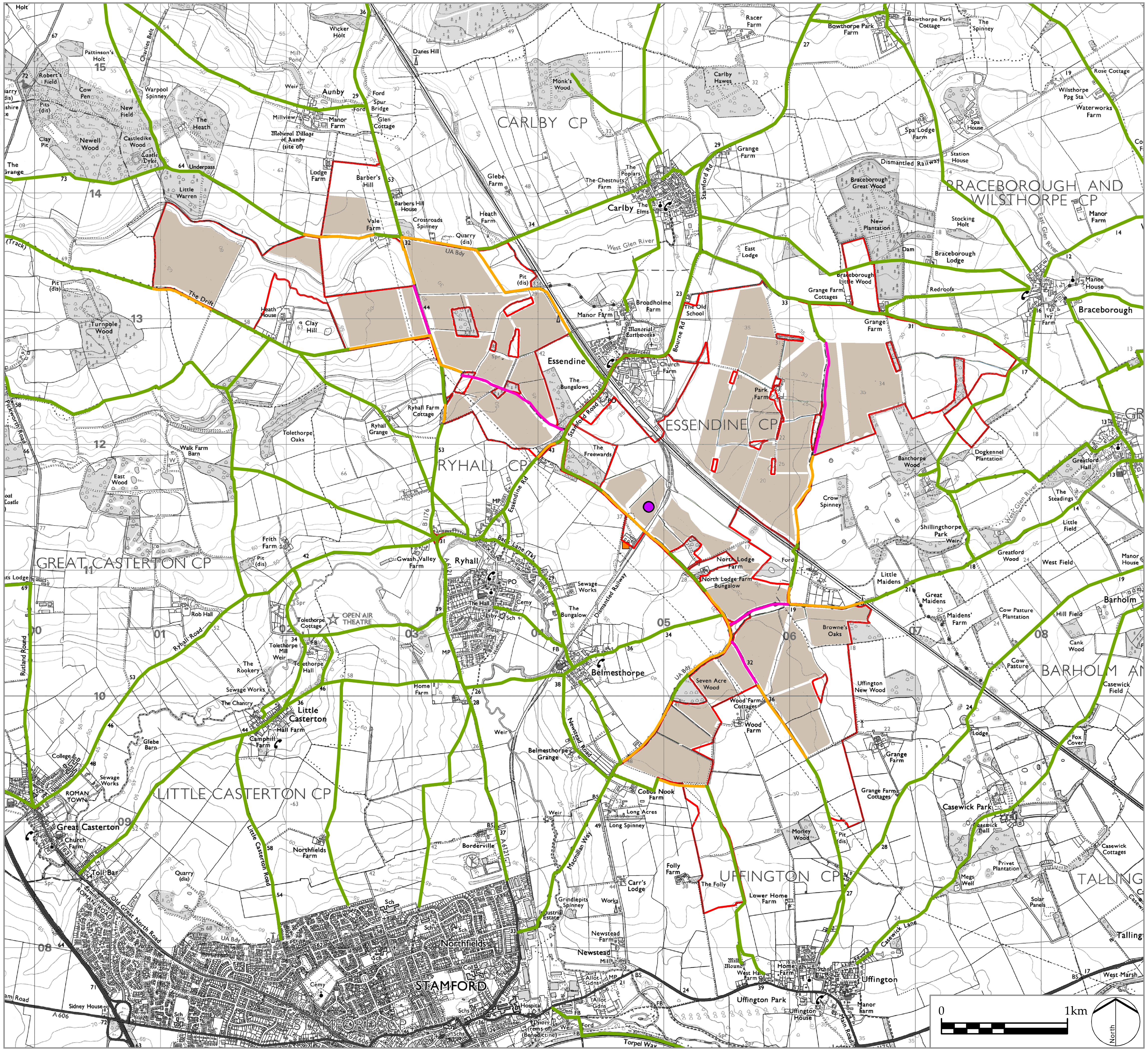
ISSUED BY	Oxford	T: 01865 887050	
DATE	Jun 2023	DRAWN	AG
SCALE @A3	1:42,000	CHECKED	BC
STATUS	Final	APPROVED	RP

DWG. NO. 7863_SK_920

No dimensions are to be scaled from this drawing.
All dimensions are to be checked on site.
Area measurements for indicative purposes only.

Sources: Ordnance Survey, Natural England, Sustrans

Z:\7863_NSIP_SOLAR_FARM_CONFIDENTIAL\8GIS\PROJECTS\7863_SK_XXX_AFFECTED_ROUTES.MXD



Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER

EN010127

LEGEND

Site Features

Order limits

National Grid Ryhall Substation

Concept Masterplan Proposals

Routes Directly Adjacent to Solar PV Site (on both sides)

Routes Directly Adjacent to Solar PV Site (on one side)

Routes Not Directly Adjacent to Solar PV Site

Solar PV Site

Onsite Substation

This plan identifies PRoW and roads within the locality of the Order limits that pass within or adjacent to the Solar PV site.

The total length of routes that run between the Solar PV site (i.e. development offset on both sides) is 3,090.11 m (3.1km).

The total length of routes that run adjacent to the Solar PV Site (i.e. development is offset on one side) is 9,159.27 m (9.2km).

REV.	DESCRIPTION	APP.	DATE
P0	Deadline 3 Submission	RP	06/11/22

Mallard Pass Solar Farm

PROJECT TITLE

MALLARD PASS SOLAR FARM

DRAWING TITLE

Routes Directly Adjacent to Solar PV Site

ISSUED BY	Oxford	T: 01865 887050	
DATE	June 2023	DRAWN	AR
SCALE @A3	1:30,000	CHECKED	RP
STATUS	Final	APPROVED	RP

DWG. NO. 7863_SK_921 REV: P0

No dimensions are to be scaled from this drawing.
All dimensions are to be checked on site.
Area measurements for indicative purposes only.

Sources: Ordnance Survey

Appendix C Sizewell C Judicial Review Judgment

Neutral Citation Number: [2023] EWHC 1526 (Admin)

Case No: CO/3147/2022

IN THE HIGH COURT OF JUSTICE
KING'S BENCH DIVISION
PLANNING COURT

Royal Courts of Justice
Strand, London, WC2A 2LL

Date: 22/06/2023

Before :

THE HON. MR. JUSTICE HOLGATE

- -

Between :

THE KING

on the application of

TOGETHER AGAINST SIZEWELL C LIMITED	**Claimant**
– and –	
SECRETARY OF STATE FOR ENERGY SECURITY AND NET ZERO	**Defendant**
– and –	
NNB GENERATION COMPANY (SZC) LIMITED	**Interested Party**

- -
- -

David Wolfe KC, **Ashley Bowes and Ruchi Parekh** (instructed by **Leigh Day Solicitors**) for the **Claimant.**
James Strachan KC and **Rose Grogan** (instructed by **Government Legal Department**) for the **Defendant.**
Hereward Phillpot KC and **Hugh Flanagan** (instructed by **Herbert Smith Freehills)** for the **Interested Party.**

Hearing dates: 22 and 23 March 2023

- -

APROVED JUDGMENT

Mr Justice Holgate:

Introduction

1. The claimant seeks to challenge by judicial review under s.118(1) of the Planning Act 2008 ("the 2008 Act") the decision dated 20 July 2022 made under s.114 of that Act to make the Sizewell C (Nuclear Generating Station) Order 2022 (SI 2022 No. 853) ("the Order") under s.114 of that Act. That decision was made by, and the proceedings were brought against, the Secretary of State for Business, Energy and Industrial Strategy. However, with effect from 7 May 2023 the relevant functions have been transferred to the Secretary of State for Energy Security and Net Zero and he has therefore been substituted as the defendant.

2. The Order grants development consent for the construction, operation, maintenance and decommissioning of a nuclear power station comprising two UK European Pressurised Reactors, each with a net electrical output of 1,670 MW, and a total capacity of 3,340 MW.

3. The claimant, Together Against Sizewell C Limited ("TASC"), is a private company. It was set up on 8 July 2022 by members of a local community group as a special purpose vehicle for the bringing of this claim and to receive public donations to that end. TASC was established in 2013 to oppose the project. It has had about 280 supporters. The group responded to pre-application consultations and participated in the statutory Examination of the draft order. It made written representations on a range of subjects and oral representations at "issue-specific hearings" ("ISHs") held during the Examination.

4. The Order granted development consent to the interested party, NNB Generation Company (SZC) Limited ("SZC").

5. The application for consent was made on 27 May 2020. The defendant appointed a panel of five inspectors ("the Panel") to conduct the Examination of the application under Chapter 4 of Part 6 of the 2008 Act. The Examination took place between April and October 2021.

6. At the time of the Examination, SZC was unable to identify a permanent supply of potable water for the project, because this was to be decided as part of the preparation and publication by Northumbrian Water Limited ("NWL") of a Water Resources Management Plan pursuant to s.37A of the Water Industry Act 1991 ("the 1991 Act") for Essex and Suffolk over the period 2025 to 2050 (referred to as WRMP24).

7. SZC produced a Water Supply Strategy Report in September 2021 which identified the amounts of potable water required during the construction, commissioning and operational phases of Sizewell C. When the station is operating the peak demand will be up to 2,800 m^3/day. This is an entirely separate issue from the cooling water needed in connection with electricity generation, which is obtained directly from the sea.

8. The Panel's Report ("PR") was submitted to the defendant on 25 February 2022. In its assessment of the benefits of the project as part of the overall planning balance the Panel relied upon the contribution of the power station to low-carbon energy production. It would meet the aim of Government policy to achieve delivery of major energy infrastructure including new nuclear electricity generation. They considered that "there is clearly an urgent need for development of the type proposed" and gave "very substantial weight" to the contribution that the scheme would make to meeting that need (PR 7.5.4).

9. Because the project is likely to have a significant effect on "European sites", an "appropriate assessment" was required to be carried out under reg.63(1) of the Conservation of Habitats and Species Regulations 2017 (SI 2017 No. 1012) ("the Habitats Regulations"). The Panel concluded that an adverse effect on the integrity of the marsh harrier feature of the Minsmere-Walberswick SPA resulting from noise and visual disturbance during the construction phase could not be excluded (PR 6.4.598). Under reg.64 the Panel advised that there were no "alternative solutions" to the proposed development (PR 6.6.12) and the defendant could conclude that the project must be carried out for "imperative reasons of overriding public interest" ("the IROPI test"). The public interest reasons included the continuing growth in the demand for electricity, the retirement of existing generation capacity, the shortfall in generation of 95GW by 2035, the scale of the need for nuclear new build, the UK's commitment to the net zero target for 2050, the continuity and reliability of supply delivered by nuclear energy as part of a diverse energy mix and the urgent need for new nuclear power stations (PR 6.7.4 and 6.7.9). The Panel also identified some additional areas where the information before them was insufficient for the purposes of the Habitats Regulations, but those matters do not give rise to any legal challenge.

10. However, there remained the outstanding issue about a permanent supply of potable water. The power station could not be licensed by the Office for Nuclear Regulation ("ONR") under the Nuclear Installation Act 1965 ("the 1965 Act") and could not be operated without such a supply. The Panel said that because an assured supply of potable water had not been identified, the cumulative environmental effects of the proposed development and that supply could not be assessed (PR 7.5.7) They stated that they could not recommend approval of the application without additional information and assurance on the provision of a permanent water supply. They regarded this "as an important matter of such magnitude that it should not be left unresolved to a future date" (PR 7.5.8). Subject to the permanent water supply issue, the Panel considered that the benefits of the proposal strongly outweighed the adverse impacts. But in view of that unresolved issue as at the close of the Examination, the Panel considered that the case for the grant of development consent had not yet been made out (PR 7.5.9 and 10.3.1)

11. On 18 March 2022 the defendant requested further information from SZC, the Environment Agency ("EA"), Natural England ("NE") and the ONR. The defendant referred to a letter from NWL's Solicitors of 23 February 2022 advising that the company was unable to meet the project's long-term demand for water supply from existing resources and that a number of demand

management and supply side options were being appraised. The defendant asked SZC to explain the progress being made to secure a permanent solution so that he could reach a reasoned conclusion on the cumulative environmental effects of different permanent water supply solutions (see DL 4.29).

12. SZC responded to that request on 8 April 2022. In summary, they relied firstly upon the duty of NWL under the 1991 Act to identify through WRMP24 new water resources to meet the demand forecast for its region, including Sizewell C. NWL would carry out an integrated environmental assessment of the Plan, including strategic environmental assessment ("SEA") under The Environmental Assessment of Plans and Programmes Regulations 2004 (SI 2004 No.1633) and a Habitats Regulations Assessment ("HRA"). These assessments would be completed before Sizewell could receive the new supply (DL 4.32). SZC submitted that the long-term planning of water supply was subject to the separate requirements of the 1991 Act and could not yet be identified for the power station (and other developments). Indeed, it could change again during the lifetime of the power station as the water undertaker manages its resources in response to *inter alia* changing demand. In accordance with national policy, the decision under the 2008 Act should be taken on the assumption that other statutory regimes will be properly applied (DL 4.33). SZC submitted that there was insufficient information on the permanent solutions that might come forward for any meaningful assessment to be made at that stage.

13. Secondly, SZC said that in the unlikely event of NWL being unable to provide a permanent supply for the power station, SZC could develop a permanent desalination plant. SZC considered that such a plant would be unlikely to generate any new or materially different significant environmental effects (DL 4.30 and 4.66).

14. On 25 April 2022 the defendant invited comments from interested parties on the responses he had received. TASC replied on 23 May 2022. They raised objections to a permanent desalination plant but offered no comments on the WRMP route. TASC maintained their position that the lack of a guaranteed water supply meant that not all significant environmental effects were being assessed at the development consent stage.

15. The defendant's decision letter was issued on 20 July 2022. The briefing to the Secretary of State for his consideration of SZC's application included the Panel's Report of some 1500 pages, the final HRA for Sizewell C and the draft decision letter, which itself ran to nearly 190 pages.

16. The defendant addressed the potable water supply issue at some length in DL 4.43 to 4.69 (reproduced in the Annex to this judgment). He was satisfied with the tankering arrangements and the temporary desalination plant proposed for the construction period and the assessment of their impacts (DL 4.43). Those conclusions are not challenged in these proceedings.

17. The defendant concluded that the proposed development and NWL's WRMP24 are separate "projects" (DL 4.49). On that basis there was no requirement for an assessment to be made of the permanent water supply solution as a part of the

power station project. He then went on to consider the Panel's view that the cumulative impacts of that water supply should nonetheless be considered at the development consent stage for the power station. The defendant concluded firstly, that a long-term water supply for Sizewell C is viable. Secondly, any proposal for the supply of water by NWL will be properly assessed under the WRMP24 process and other relevant regulatory regimes. Thirdly, no further information was required on that subject for the application for development consent to be determined (DL 4.67). Disagreeing with the Panel, the defendant did not consider the present uncertainty over the permanent water supply strategy to be a barrier to granting development consent for the project (DL 4.68).

18. The remainder of this judgment is set out under the following headings:

Heading	Paragraph Number
Grounds of challenge	19-23
Statutory framework	24-49
The Planning Act 2008	24-34
Water Industry Act 1991	35-40
The Nuclear Installations Act 1956	41
The Conservation of Habitats and Species Regulations 2017	42-45
The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017	46-49
Ground 1	50-93
A summary of the claimant's submissions	50-53
NWL's position on water supply	54-64
The decision letter	65-68
Discussion	69-93
Ground 2	94-105
Discussion	97-105
Ground 3	106-114
Ground 4	115-132
Discussion	120-132
Ground 5	133-152
Discussion	137-152
Ground 6	153-177
Discussion	157-177
Ground 7	178-187
Discussion	180-187
Conclusions	188-191
Annex – paragraphs 4.43 – 4.69 of the Secretary of State's decision letter	

The grounds of challenge

19. In summary the claimant seeks to advance the following grounds of challenge:

> **Ground 1**: Contrary to reg.63(1) of the Habitats Regulations the defendant failed to assess the environmental impacts of the "project" (including the necessary permanent potable water supply solution).
>
> **Ground 2**: In the alternative, contrary to reg.63(1), the defendant failed to assess cumulatively the environmental impacts of the power station together with those of the permanent potable water supply solution.
>
> **Ground 3**: The defendant failed to supply lawfully adequate reasons for departing from the advice of NE that the permanent water supply should be considered to be a fundamental component of the "operation of the project" and its effects at this stage.
>
> **Ground 4**: Contrary to reg.64(1) of the Habitats Regulations, the defendant also failed lawfully to consider "alternative solutions" to the power station before concluding that there were imperative reasons of overriding public interest justifying the environmental harm it would cause.
>
> **Ground 5**: The defendant took into account a legally irrelevant consideration (because it was supported by no evidence), namely the contribution the power station might make to reducing greenhouse gas ("GHG") emissions by 78% from 1990 levels by 2035.
>
> **Ground 6**: The defendant also acted irrationally in concluding that the power station site would be clear of nuclear material by 2140 and/or failed to supply adequate reasons for rejecting the claimant's case on that point.
>
> **Ground 7**: The defendant also erred in law in concluding that the power station's operational GHG emissions would not have a significant effect on the UK's ability to meet its climate change obligations.

20. On 19 October 2022 Kerr J refused the claimant permission to apply for judicial review on the papers.

21. On the same day the claimant filed an application to amend its statement of facts and grounds to add a new ground 8. The claimant then renewed its application for permission on grounds 1 to 7.

22. On 14 December 2022 I refused permission for the claimant to add ground 8. Having regard to the parties' submissions, I also ordered that the renewed

application for permission should be adjourned to a rolled-up hearing. On 10 January 2023 the claimant withdrew its renewed application for permission to argue ground 8.

23. Projects such as Sizewell C may attract both strong opposition and strong support. It is therefore necessary to reiterate what was said by the Divisional Court in *R (Rights: Community: Action) v Secretary of State for Housing, Communities and Local Government* [2021] PTSR 553 at [6]:

> "6. It is important to emphasise at the outset what this case is and is not about. Judicial review is the means of ensuring that public bodies act within the limits of their legal powers and in accordance with the relevant procedures and legal principles governing the exercise of their decision-making functions. The role of the court in judicial review is concerned with resolving questions of law. The court is not responsible for making political, social, or economic choices. Those decisions, and those choices, are ones that Parliament has entrusted to ministers and other public bodies. The choices may be matters of legitimate public debate, but they are not matters for the court to determine. The court is only concerned with the legal issues raised by the claimant as to whether the defendant has acted unlawfully. The claimant contends that the changes made by the SIs are radical and have been the subject of controversy. But it is not the role of the court to assess the underlying merits of the proposals. Similarly, criticism has been made of the way in which, or the speed with which, these changes were made. Again, these are not matters for the court to determine save and in so far as they involve questions concerning whether or not the appropriate legal procedures for making the changes were followed."

Statutory framework

The Planning Act 2008

24. The 2008 Act provides a dedicated regime for applications to be made for the grant of development consent orders for "nationally significant infrastructure projects" ("NSIPs"). The framework of the Act has been set out in a number of authorities and need not be repeated in detail here. I refer in particular to the decision of the Supreme Court in *R (Friends of the Earth Limited) v Secretary of State for Transport* PTSR 190 at [19] to [37].

25. One of Parliament's aims was to make the application of development control to NSIPs more efficient and to reduce delays in decision-making. Issues such as the need for different types of infrastructure and the policy of the Government on such development was to be settled in advance by National Policy Statements ("NPSs"). A draft version of a NPS is subject to SEA, HRA, consultation, public involvement and Parliamentary scrutiny before being designated by the relevant Minister by statutory instrument under s.5 of the 2008 Act.

26. Under s.104(2), when determining an application for development consent, the Secretary of State must have regard to any NPS which "has effect" in relation to development of the description to which that application relates (a "relevant NPS"). Under s.104(3) he must determine the application in accordance with that relevant NPS, save to the extent that one or more of the exceptions in s.104(4) to (8) applies. Section 105 applies in relation to an application for an order granting development consent if s.104 does not apply. Section 105(2) provides that in deciding the application the Secretary of State must have regard to *inter alia* any matters which he considers are both important and relevant to his decision. Section 106 enables the Secretary of State to disregard any representation (including evidence) which he considers *inter alia* relates to the merits of policy set out in a NPS. Section 106 applies whether an application is subject to s.104 or to s.105.

27. In the present case there were two relevant NPSs, the Overarching National Policy Statement for Energy (EN-1) and the National Policy Statement for Nuclear Power Generation (EN-6). Both documents were "designated" by the defendant in July 2011.

28. Paragraphs 3.1.1 to 3.1.4 of EN-1 set out the approach for deciding applications for development consent. The UK needs all the types of energy infrastructure covered by the NPS, which include nuclear power, in order to achieve energy security and reduce GHGs dramatically. Applications should be determined on the basis that the need for these types of infrastructure has been demonstrated in the NPS. There is an urgent need for new nuclear power generation which will play an increasingly important role (para 3.5.1). It is Government policy that new nuclear power should be able to contribute as much as possible to the UK's need for new capacity (para. 3.5.2). New nuclear power stations will help to ensure a diverse mix of technology and fuel sources, increasing the resilience of the UK's energy system (para. 3.5.3). New nuclear power forms one of the three key elements of the Government's strategy for moving towards a decarbonised, diverse electricity sector by 2050 (para. 3.5.5). Given the urgent need for low carbon forms of electricity, it is important that new nuclear power stations are constructed and operational as soon as possible "and significantly earlier than 2025." Accordingly, the sites identified in Part 4 of EN-6 were those considered to be capable of deployment by the end of 2025 (paras 3.5.9 and 3.5.10).

29. EN-6 contains similar policy statements (paras. 2.2.1 and 2.2.2). In Part 4 of EN-6 Sizewell was identified as a potentially suitable site for a new nuclear power station along with Hinkley Point and six other sites.

30. On 7 December 2017 the Government issued a Written Ministerial Statement announcing a consultation document on designating in a NPS potentially suitable sites for nuclear power stations expected to be deployed after 2025 and before the end of 2035. The Government stated that EN-6 only has effect for the purposes of s.104 of the 2008 Act in relation to a project expected to be deployed before the end of 2025, that is when a station first begins to feed electricity into the national grid. The statement says that s.105 of the 2008 Act applies to EN-6 in so far as s.104 does not. For projects due to be deployed beyond 2025 the Government continues to give its strong in principle support to proposals for

those sites listed in EN-6. Both EN-1 and EN-6 contain information, assessments and statements which continue to be important for projects being deployed after 2025.

31. The Panel considered that the application for Sizewell C should be assessed under s.105 and that EN-1 and EN-6 were important considerations. There have been no relevant changes in circumstances reducing the weight to be given to those policies. The acceptability of the proposal in terms of planning policy should be assessed primarily against the nuclear-specific policies in the NPSs. The defendant agreed with the Panel (DL 4.4 and 4.5).

32. The defendant also agreed with the Panel's assessment of the need for nuclear power projects, to which he attached substantial weight. Thus, there is an urgent need for new nuclear energy generating infrastructure of the kind proposed at Sizewell. The contribution that the development would make to the delivery of low carbon energy would assist in the decarbonisation of the UK economy in line with the UK's obligations under the Paris Agreement (DL 4.5 to DL 4.11).

33. The main consequence of s.105 of the 2008 Act applying to the determination of SZC's application was that the presumption in s.104(3) did not apply. Thus, the defendant did not have to decide the application in accordance with the NPS unless one or more of the exceptions in s.104(4) to (8) applied. Nevertheless, it is relevant to note that where s.104 is engaged, the balancing exercise described in s.104(7) may not be used to circumvent s.106(1)(b), which has the effect of preventing challenges to the merits of policy in a NPS in an Examination or before the Secretary of State. So, for example, changes of circumstance after the designation of a NPS are to be addressed instead through the process under s.6 for a formal review of a NPS (*R (ClientEarth) v Secretary of State for Business, Energy and Industrial Strategy* [2021] PTSR 1400 at [105]; *R (Spurrier) v Secretary of State for Transport* [2020] PTSR 240 at [106] to [110]).

34. There is no dispute that the NPSs were material considerations for the defendant to take into account under s.105 when determining SZC's application. Section 106 applies to a determination by the Secretary of State under s.105 just as it does to a decision under s.104. Accordingly, the provisions in the 2008 Act preventing challenges to the merits of policy in a NPS were applicable. Although a review of EN-6 under s.6 of the 2008 Act is being carried out, the defendant has decided not to exercise the power in s.11 to suspend either EN-1 or EN-6 pending the completion of that review.

Water Industry Act 1991

35. Section 37(1) lays down a general duty on every water undertaker in the following terms:

> "(1) It shall be the duty of every water undertaker to develop and maintain an efficient and economical system of water supply within its area and to ensure that all such arrangements have been made—

> (a) for providing supplies of water to premises in that area and for making such supplies available to persons who demand them; and
>
> (b) for maintaining, improving and extending the water undertaker's water mains and other pipes,
>
> as are necessary for securing that the undertaker is and continues to be able to meet its obligations under this Part."

This primary duty is enforceable by the Secretary of State or OFWAT under s.18 of the 1991 Act.

36. Water undertakers are legally obliged to plan to meet demand within their area through a Water Resource Management Plan. Section 37A provides so far as material:

> "(1) It shall be the duty of each water undertaker to prepare, publish and maintain a water resources management plan.
>
> (2) A water resources management plan is a plan for how the water undertaker will manage and develop water resources so as to be able, and continue to be able, to meet its obligations under this Part.
>
> (3) A water resources management plan shall address in particular—
>
> (a) the water undertaker's estimate of the quantities of water required to meet those obligations;
>
> (b) the measures which the water undertaker intends to take or continue for the purpose set out in subsection (2) above (also taking into account for that purpose the introduction of water into the undertaker's supply system by or on behalf of water supply licensees);
>
> (c) the likely sequence and timing for implementing those measures; and
>
> (d) such other matters as the Secretary of State may specify in directions (and see also section 37AA).
>
> (4) The procedure for preparing and publishing a water resources management plan (including a revised plan) is set out in section 37B below.
>
> (5) Before each anniversary of the date when its plan (or revised plan) was last published, the water undertaker shall —
>
> (a) review its plan; and

> (b) send a statement of the conclusions of its review to the Secretary of State.
>
> (6) The water undertaker shall prepare and publish a revised plan in each of the following cases—
>
> (a) following conclusion of its annual review, if the review indicated a material change of circumstances;
>
> (b) if directed to do so by the Secretary of State;
>
> (c) in any event, not later than the end of the period of five years beginning with the date when the plan (or revised plan) was last published,
>
> and shall follow the procedure in section 37B below (whether or not the revised plan prepared by the undertaker includes any proposed alterations to the previous plan).
>
> (7) …."

37. Under s.37AA(8) before preparing its WRMP the water undertaker must consult *inter alia* the EA, OFWAT and the Secretary of State.

38. Section 37B lays down the procedure for the preparation and publication of a WRMP. The undertaker is obliged to publish a draft of the plan so that representations may be made on its proposals to the Secretary of State (s.37B(3)). The WRMP must be sent to *inter alia* OFWAT, the EA, NE and Historic England so that they too may make representations (see reg.2 of The Water Resources Management Plan Regulations 2007 (SI 2007 No.727)). The undertaker may then comment on those representations (s.37B(4)). The Secretary of State may cause a public inquiry or hearing to be held to consider any issues arising (s.37B(5) and reg.5 of the 2007 Regulations). The Secretary of State has the power to direct that the WRMP must differ from the draft sent to him and the undertaker must then comply with that direction (s.37B(7)). The undertaker must publish the final version of the plan (s.37B(9)).

39. The duties of a water undertaker under s.37A and s.37B are enforceable by the Secretary of State under s.18.

40. Where the owner or occupier of premises in the area of a water undertaker requests a supply of water for non-domestic purposes it is the undertaker's duty, in accordance with terms and conditions determined under s.56, to take steps to provide that supply. Those terms and conditions are to be determined by agreement between the parties or, in default, by OFWAT according to what appears to it to be reasonable. Section 55(3) qualifies the duty under s.55:

> "A water undertaker shall not be required by virtue of this section to provide a new supply to any premises, or to take any steps to enable it to provide such a supply, if the provision of that supply or the taking of those steps would—

> (a) require the undertaker, in order to meet all its existing obligations to supply water for domestic or other purposes, together with its probable future obligations to supply buildings and parts of buildings with water for domestic purposes, to incur unreasonable expenditure in carrying out works; or
>
> (b) otherwise put at risk the ability of the undertaker to meet any of the existing or probable future obligations mentioned in paragraph (a) above."

Any dispute arising under s.55(3) is determined by OFWAT (s.56(2)).

The Nuclear Installations Act 1965

41. The use of a site for the installation and operation of a nuclear reactor is prohibited unless authorised by a nuclear site licence by the "appropriate national authority", the ONR (ss. 1 and 3). When granting a licence the ONR must attach such conditions as it considers necessary or desirable in the interests of safety and may also attach conditions to the licence at any time (s.4(1)). Conditions may be attached providing for *inter alia* the design, construction, operation, siting or modification of any plant or other installation on the site (s.4(3)(b)).

The Conservation of Habitats and Species Regulations 2017

42. The defendant is a "competent authority" for the purposes of the Habitats Regulations. Regulations 63 and 64 apply in relation to the making of an order granting development consent under the 2008 Act (regs. 62(1) and 84(1)).

43. In so far as is material, reg.63 provides:

> "(1) A competent authority, before deciding to undertake, or give any consent, permission or other authorisation for, a plan or project which—
>
> (a) is likely to have a significant effect on a European site or a European offshore marine site (either alone or in combination with other plans or projects), and
>
> (b) is not directly connected with or necessary to the management of that site,
>
> must make an appropriate assessment of the implications of the plan or project for that site in view of that site's conservation objectives.
>
> (2) A person applying for any such consent, permission or other authorisation must provide such information as the competent authority may reasonably require for the purposes of the assessment or to enable it to determine whether an appropriate assessment is required.

> (3) The competent authority must for the purposes of the assessment consult the appropriate nature conservation body and have regard to any representations made by that body within such reasonable time as the authority specifies.
>
> (4) It must also, if it considers it appropriate, take the opinion of the general public, and if it does so, it must take such steps for that purpose as it considers appropriate.
>
> (5) In the light of the conclusions of the assessment, and subject to regulation 64, the competent authority may agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the European site or the European offshore marine site (as the case may be).
>
> (6) In considering whether a plan or project will adversely affect the integrity of the site, the competent authority must have regard to the manner in which it is proposed to be carried out or to any conditions or restrictions subject to which it proposes that the consent, permission or other authorisation should be given.
>
> …"

The "appropriate nature conservation" body in this case was NE (reg.5(1)).

44. Regulation 64(1) provides:

> "(1) If the competent authority is satisfied that, there being no alternative solutions, the plan or project must be carried out for imperative reasons of overriding public interest (which, subject to paragraph (2), may be of a social or economic nature), it may agree to the plan or project notwithstanding a negative assessment of the implications for the European site or the European offshore marine site (as the case may be)."

It is not suggested that reg.64(2) was engaged in this case.

45. In relation to the application of regs.63 and 64 to the development consent procedure, reg.84(2) provides:

> "(2) Where those provisions apply, the competent authority may, if it considers that any adverse effects of the plan or project on the integrity of a European site or a European offshore marine site would be avoided if the order granting development consent included requirements under section 120 of the Planning Act 2008 (what may be included in order granting development consent), make an order subject to those requirements."

The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017

46. Regulation 4 of the Infrastructure Planning (Environmental Impact Assessment Regulations 2017 (SI 2017 No. 572) ("the EIA Regulations") prohibits the Secretary of State from making an order granting development consent for "EIA development" under the 2008 Act unless EIA has been carried out (reg.4). Sizewell C constituted EIA development. By reg.5 "EIA" is a process consisting of the preparation of an "environmental statement" ("ES"), the carrying out of consultation under the EIA Regulations and compliance by the defendant with reg.21. Regulation 21 required the defendant when deciding whether to make the development consent order, to examine the environmental information and, taking that into account, to reach a reasoned conclusion on the significant effects of the development on the environment to integrate that conclusion into the decision on whether to grant the order, and to consider whether it was appropriate to impose monitoring measures. Environmental information "means the ES and the representations made by statutory consultees and other persons about the environmental effects of the development" (reg.3(1)).

47. Regulation 5(2) and (3) of the EIA Regulations provides:

> "(2) The EIA must identify, describe and assess in an appropriate manner, in light of each individual case, the direct and indirect significant effects of the proposed development on the following factors—
>
> (a) population and human health;
>
> (b) biodiversity, with particular attention to species and habitats protected under Directive 92/43/EEC and Directive 2009/147/EC;
>
> (c) land, soil, water, air and climate;
>
> (d) material assets, cultural heritage and the landscape;
>
> (e) the interaction between the factors referred to in sub-paragraphs (a) to (d).
>
> (3) The effects referred to in paragraph (2) on the factors set out in that paragraph must include the operational effects of the proposed development, where the proposed development will have operational effects."

48. Regulation 14 prescribes the contents of an ES. It must include a description of "the likely significant effects of the proposed development on the environment" (reg.14(2)(b)). By reg.14(2)(f) the ES must contain any additional information specified in sched. 4 relevant to "the specific characteristics of the particular development or type of development and to the environmental features likely to be significantly affected". Paragraph 5 of sched. 4 refers to:

> "A description of the likely significant effects of the development on the environment resulting from, *inter alia* –

> …
>
> (e) the cumulation of effects with other existing and/or approved projects, taking into account any existing environmental problems relating to areas of particular environmental importance likely to be affected or the use of natural resources;
>
> …"

49. Regulation 14(3) provides (so far as is relevant):

> "The environmental statement referred to in paragraph (1) must–
>
> (a) …
>
> (b) include the information reasonably required for reaching a reasoned conclusion on the significant effects of the development on the environment, taking into account current knowledge and methods of assessment; and
>
> (c) … "

Ground 1

A summary of the claimant's submissions

50. The claimant submits that in breach of reg.63 of the Habitats Regulations the defendant failed to make an appropriate assessment of the implications of the "project" for European sites because he wrongly excluded from that project the permanent potable water supply solution without which the project is incomplete and cannot function. As at the date of the decision to make the order, that solution would potentially give rise to further impacts on protected areas which have not been assessed and could not be ruled out.

51. The permanent potable water supply was a fundamental component of the operation of the power station according to NE (para. 2.1.2. of representations in October 2021). The defendant agreed with the ONR that in order to satisfy the conditions of any nuclear site licence for the project, SZC will have to put in place a reliable supply of water before any nuclear safety related activities can take place that are dependent on such a supply.

52. The nuclear power station is functionally interdependent with the permanent water supply solution (*R (Wingfield) v Canterbury City Council* [2020] J.P.L 154 at [64]).

53. The reasons advanced by the defendant as to why the permanent water supply did not form part of the power station project are irrelevant. The claimant relies in particular upon *R (Ashchurch Parish Council) v Tewksbury Borough Council* [2023] EWCA Civ 101.

NWL's position on water supply

54. SZC's Water Supply Strategy Report (September 2021) summarised NWL's position as at that stage. The local "water resource zone" Blyth WRZ would be unable to supply water to meet the needs of the power station. NWL had identified the possibility of a connection being made to the Northern/Central WRZ which might have sufficient capacity in the River Waveney, subject to completion of NWL's part of the Water Industry National Environment Programme ("WINEP") study led by the EA. This would require the construction of a new transfer main from Barsham Water Treatment Works to Saxmundham, a distance of 28km, and other water network enhancements. The proposed transfer main would connect into the local Blyth distribution network at Saxmundham Water Tower and at other locations. "These local connections have the potential to provide significant legacy benefit by increasing capacity and resilience of the distribution network" (para 3.2.3 and DL 4.53). The main would benefit consumers in the local area and not simply Sizewell. There were issues affecting the availability of a sustainable supply across the whole of the East of England, which, if confirmed, would require a strategic response by NWL so that it could discharge its duties under the 1991 Act. Accordingly, longer term plans would need to be put in place by NWL "to serve the region and its committed growth."

55. In the decision letter the defendant noted that the transfer main from Barsham to Saxmundham did not form part of SZC's application for development consent (DL 4.59). But SZC had been able to provide information on the environmental impact of that pipeline and concluded that this would not give rise to any new or different significant cumulative impacts (DL 4.65). The defendant agreed (DL 4.51 to 4.52).

56. On 14 September 2021 the Panel held Issue Specific Hearing 11 ("ISH 11"), which covered water supply issues (DL 4.18). SZC provided a written note on issues arising out of that hearing, including the legal framework for WRMPs and the legal obligations of NWL.

57. On 5 October 2021 the Panel held ISH 15. A statement of common ground was agreed between NWL and SZC on 8 October 2021. In that statement NWL said that it would confirm whether it would be able to meet Sizewell C's long-term needs from the Northern/Central WRZ following completion of the WINEP modelling. If it could not, then NWL would have to develop new supply schemes through WRMP24, but that would not meet Sizewell C's long-term needs until the late 2020s at the earliest. The parties agreed 2032 as the backstop date for this long-term supply to be fully available.

58. NWL was represented by counsel at ISH 15 and agreed with SZC's position at the hearing. SZC pointed out that the Water Resources Planning Guidelines state that water undertakers must ensure that their planned property and population forecasts and resulting supply "must not constrain planned growth". Accordingly, even if NWL could not at that stage identify a water supply for Sizewell C, it was obliged to do so. NWL confirmed that that was the case.

59. After the Examination had closed on 14 October 2021, NWL's solicitors wrote to the defendant on 23 February 2022 to provide an update on the permanent supply of potable water. They said that the WINEP modelling showed that NWL would "not be able to supply all forecast household and non-household demand, including the Project's long-term demand, from existing water resources". "NWL will therefore need to identify new water resources to meet the forecast demand". NWL had included SZC's demand figures from 2032 in its WRMP24 demand forecast for the Suffolk supply area.

60. NWL stated that in addition to demand management options (e.g. reduction in leakage from networks and compulsory metering of households), it was appraising options which included:

(i) Imports from Anglian water (subject to exporting water from the Essex WRZ);

(ii) Nitrate removal at Barsham water treatment works to reduce raw sewage outages;

(iii) Effluent re-use and desalination;

(iv) Winter reservoirs post-2035.

The options in the WRMP24, due for submission to Defra by October 2022, would depend on the final WINEP modelling of abstraction in the River Waveney.

61. NWL reiterated its commitment to providing a long-term supply for Sizewell C, although it was unlikely to be available before the late 2020s at the earliest. This was dependent on finalising and funding new supply schemes to meet future demands in Suffolk, including the power station.

62. On 8 April 2022 SZC provided its response to the defendant's request dated 18 March 2022 for further information. The document summarised the submissions and information already supplied and stated that there was no difference between the positions of SZC and NWL. SZC summarised the range of options being considered by NWL, which included water transfer. It emphasised that WRMP24 would be subject to SEA and HRA. NWL had said that after submitting its plan for consultation it would work with SZC to negotiate an agreement under s.55 of the 1991 Act. Paragraphs 2.1.16 and 2.1.17 read as follows:

> "2.1.16 It is because the long-term planning of water supply is the subject of separate statutory provisions and processes that the identification of the source of Sizewell's long-term supply cannot be known at this stage. Indeed, the source may well change during the lifetime of the power station as the undertaker develops and manages its water resources in response to changing demand and other considerations. For the same reasons, and because on the evidence the source of supply is unlikely to be a constraint to the construction and operation of

> the new power station, the source does not need to be known for the purposes of the DCO.
>
> 2.1.17 NPS EN-1 is clear that that the DCO decision maker should work on the assumption that other regimes and regulatory processes will be properly applied and enforced so that decisions on DCO applications should complement but not seek to duplicate other processes (NPS EN-1 paragraph 4.10.3). That same principle is clear from paragraph 188 of the NPPF, i.e. planning decisions should assume that regimes will operate effectively."

SZC stated that it had put in place plans for a temporary desalination unit which would cover the project's water requirements up to the commissioning of unit 1 of the power station. That would give NWL 10 years to plan for and deliver a permanent water supply.

63. TASC sent to the defendant representations in response by letters dated 8 April 2022 and 23 May 2022. The first made criticisms of the proposal for a temporary desalination plant and said nothing about WRMP24. The second objected to a possible location for a permanent desalination plant and again said nothing about WRMP24. They made a general point to the effect that SZC had failed to assess impacts on receptors in relation to a permanent water supply solution, relying on the views of NE.

64. On 16 June 2022 SZC responded to the defendant's request for further information about any progress made with NWL. They said that NWL had confirmed that draft WRMP24 would make full provision for the long-term demand from Sizewell C and that, subject to the necessary approvals from Defra and OFWAT, it is likely to be possible to deliver the necessary infrastructure. NWL and SZC had agreed to begin negotiations under the 1991 Act in October 2022 for funding the design and delivery of infrastructure specific to Sizewell C, so as to be ready to sign an agreement once NWL's Business Plan had been approved by OFWAT, most likely in early 2024. SZC said that there was no reason to think that a new water supply scheme for a "critical NSIP" would not be approved in the 2024 Price Review and every reason to expect that NWL, using reasonable endeavours, would be able to deliver the necessary infrastructure for the permanent water supply connection before the end of construction of Sizewell C (see also DL 4.42).

The decision letter

65. This material on NWL's position regarding a permanent water supply was well summarised in the defendant's decision letter at DL 4.12 to 4.42. At DL 4.44 the defendant considered that the options identified by NWL were potentially viable solutions, as was the "fall back" of SZC providing a permanent desalination plant. He concluded that if development consent were to be granted for the power station, there was a "reasonable level of certainty" that a permanent solution could be found before the commissioning of the first reactor. Plainly in arriving at that conclusion the defendant would have taken into account his further conclusions about the need for environmental impacts to be

assessed and considered. The defendant's confidence that a permanent solution would be provided before operation of the power station was a matter for his judgment.

66. The defendant also noted that if, and only if, the WRMP process fails to provide a solution, SZC will have to consider providing its own permanent desalination plant (DL 4.60). He noted the objections which had been raised to this possible option and said that a detailed assessment of the impacts would be required if it were to be pursued. The defendant had not asked for an assessment at this stage because (a) this option did not form part of the proposed development and (b) SZC's position was that it was unlikely to be required (DL 4.61).

67. The defendant dealt with environmental assessment in relation to a mains link to Barsham water treatment works, the WRMP process and the possible fallback of a permanent desalination scheme between DL 4.43 to DL 4.69 in some detail. That section needs to be read as a whole.

68. Part 6 of Sched.19 to the Order contains provisions for the protection of NWL. Paragraph 70 states that subject to either condition 1 or condition 2 being satisfied, and subject to the terms of any agreement made under s.55 or determination made by OFWAT under s.56 of the 1991 Act, NWL will use its reasonable endeavours to supply Sizewell C with the quantities of water required for its operational phase as soon as reasonably practicable. Condition 1 is that the EA confirms the new annual licensed quantities which may be abstracted from the River Waveney and NWL confirms to SZC that there is a sufficient resource in the Northern/Central WRZ to meet forecast demand from its existing and future customers, including demand for Sizewell C (paras.71 to 72). Condition 2 is satisfied if there are new supply schemes in WRMP24, the Secretary of State for Environment, Food and Rural Affairs approves the publication of the final version of WRMP24 and OFWAT approves "the required supply schemes" from the approved WRMP24 in its Final Determination for the 2024 Price Review (paras. 73 to 75).

Discussion

69. Neither the Habitats Regulations nor the EIA Regulations define a "project". It is common ground in this case that principles in the case law on the EIA Regulations are applicable when considering the scope of a project under the Habitats Regulations.

70. The question of what is the project in any particular case is a matter of judgment for the decision-maker, here the Secretary of State. That judgment may only be challenged in this court on *Wednesbury* principles (*Bowen-West v Secretary of State for Communities and Local Government* [2012] Env.L.R. 22 at [39] to [42]; *Smyth v Secretary of State for Communities and Local Government* [2015] PTSR 1417; *Wingfield* at [63] and *Ashchurch* at [81], [83], [100] and [105].) In the present case the issue is whether the defendant took into account a consideration which was legally irrelevant and, if not, whether his judgment was otherwise irrational. The threshold for irrationality in the making of such a judgment is a difficult obstacle to surmount (see e.g. *Newsmith Stainless Limited*

v Secretary of State for the Environment, Transport and the Regions [2017] PTSR 1126).

71. The courts have been astute to detect "salami-slicing", that is the device of splitting a project into smaller components that fall below the threshold for "EIA development" so as to avoid the requirement to carry out EIA altogether (*R v Swale Borough Council ex parte RSPB* [1991] 1 PLR 6 at [16]; *Preston New Road Action Group v Secretary of State for Communities and Local Government* [2018] Env.L.R 18 at [69]).

72. In *R (Larkfleet Limited) v South Kesteven District Council* [2016] Env.L.R. 4 stated at [36] that it is clear from the legislation that the mere fact that two sets of proposed works have a cumulative effect on the environment does not make them a single project. Instead, they may constitute two projects but with cumulative effects which need to be assessed. The court went on to discuss a second type of salami-slicing ([37]-[38]). It acknowledged that the scrutiny of cumulative effects between two projects may involve less information than if the two sets of works are treated together as one project. Accordingly, a planning authority should be astute to ensure that a developer has not sliced up what is in reality one project in order to try to make it easier to obtain planning permission for the first part of the project and thereby gain a foot in the door in relation to the remainder. But the Directives and jurisprudence of the European Court of Justice recognise that it is legitimate for different development proposals to be brought forward at different times, even though they may have a degree of interaction, if they are different "projects". The Directives apply in such a way as to ensure appropriate scrutiny to protect the environment, whilst avoiding undue delay in the operation of the planning control system. Undue delay would be likely if all the environmental effects of every related set of works had to be definitively examined before any of those works could be allowed to proceed. Where two or more linked sets of works are in contemplation, which are properly to be regarded as distinct "projects", the objective of environmental protection is sufficiently secured under the Directives by consideration of their cumulative effects, so far as that is reasonably possible, when permission for the first project is sought, combined with the requirement for subsequent scrutiny under the Directives for the second and each subsequent project.

73. In *Wingfield* at [64] Lang J indicated some factors which *may* be taken into account in determining the extent of a project:

> "64. Relevant factors may include:
>
> i) Common ownership – where two sites are owned or promoted by the same person, this may indicate that they constitute a single project (*Larkfleet* at [60])
>
> ii) Simultaneous determinations – where two applications are considered and determined by the same committee on the same day and subject to reports which cross refer to one another, this may indicate that they constitute a single project (*Burridge* at [41] and [79]);

> iii) Functional interdependence – where one part of a development could not function without another, this may indicate that they constitute a single project (*Burridge* at [32], [42] and [78]);
>
> iv) Stand-alone projects – where a development is justified on its own merits and would be pursued independently of another development, this may indicate that it constitutes a single individual project that is not an integral part of a more substantial scheme (*Bowen-West* at [24 – 25])"

The judge made it clear that these factors were not exhaustive. The weight to be given to them will depend upon the circumstances of each case and is a matter for the decision maker.

74. Interdependence would normally mean that *each* part of the development is dependent on the other, as, for example, in *Burridge v Breckland District Council* [2013] JPL 1308 at [32] and [42].

75. At DL 4.46 the defendant referred to para 5.15.6 of EN-1 which requires the decision-maker to take into account the interaction of a proposed project with WRMPs (DL 4.46). He had regard to SZC's analysis of the obligations of NWL under the 1991 Act to prepare WRMP24 and to supply water (e.g. DL 4.47, 4.49 to 4.50, 4.55 to 4.60, 4.64 to 4.65 and 4.67). He accepted the key components of that analysis.

76. The defendant's conclusions included the following:

(i) SZC's preferred solution was a link to Barsham *provided by NWL*. SZC's cumulative assessment stated that the pipeline would follow existing roads and boundaries wherever possible. Cut and fill would progress quickly and would impact upon a single receptor for a small number of days at most. Given the footprint and locations of the works ecological impacts "would be minimal and avoidable or mitigable". There would be no significant cumulative effects. The defendant agreed. (DL 4.50 to DL 4.52 and 4.58);

(ii) If NWL's solution for the permanent supply of potable water should require a change to that pipeline connection, that would be subject to its own environmental assessment, including HRA. This would be for NWL to assess (DL 4.56 and 4.58);

(iii) WRMP24 will need to identify new water resources to meet long-term demand in Suffolk, both household and non-household demand. Those new supplies are not limited to meeting the demand for Sizewell C (DL 4.55);

(iv) Sizewell C and the WRMP24 process for identifying new water sources are separate or standalone projects, given that NWL has a duty to undertake WRMP24 regardless of whether Sizewell C proceeds. These two projects have separate "ownership" and "are subject to distinct and

asynchronous determination processes". The WRMP process is carried out by NWL and is not something that SZC can dictate (DL 4.49 and 4.60);

(v) Assessment of potential environmental impacts associated with the permanent water supply to be provided by NWL could not be carried out because of the stage reached in the WRMP24 process and the fact that the preferred solution was unknown (DL 4.50 and 4.59);

(vi) Any pipeline or connection needed for the solution adopted by NWL will be the subject of a separate application by that company. That infrastructure does not form part of the current application (DL 4.57 and 4.59);

(vii) The defendant was satisfied with the control that will be exercised by the ONR through the conditions of the nuclear site licence, which will require a reliable supply of potable water to be in place before any nuclear safety-related activities can take place. The cumulative or in-combination environmental effects will be assessed under NWL's WRMP24 process, including a HRA, before operation can commence (DL 4.64);

(viii) The provision of a permanent water supply is not an integral part of the Sizewell C proposal (DL 4.65).

77. Plainly this is not a case where the promoter of a project has sliced up the development in order to make it easier to obtain consent for the first part of a larger project. Sizewell C was initially promoted on the basis that NWL would meet its obligations under the 1991 Act by providing a permanent water supply at Barsham and a transfer main to Saxmundham. Accordingly, the provision of that infrastructure by NWL was not included in SZC's application for development consent. The present uncertainty about what form the long term supply will take only emerged subsequently. In the circumstances, it is inappropriate for the claimant to say that SZC has caused uncertainty by "keeping its options open". SZC has had to react to the changing circumstances of the WINEP modelling and NWL's evolving response to that assessment. SZC has made it plain that it wishes to rely upon the solution that NWL says it will be able to deliver through the WRMP24 process and not upon permanent desalination on-site. On the other hand the defendant's decision recognises that in the unlikely event of NWL being unable to provide a solution, SZC would seek to provide a desalination plant (DL 4.66).

78. In summary, the claimant submits that the defendant took into account the following irrelevant considerations:

(i) The current uncertainty as to the final source of the water supply was irrelevant. The lack of definition of that supply cannot "of itself" provide the answer to the question whether that supply forms part of the project;

(ii) The infrastructure for the potable water supply did not form part of the application for development consent;

(iii) The potable water supply would be subject to a separate and asynchronous decision process;

(iv) Separate ownership.

79. The claimant seeks to base these criticisms upon *Ashchurch*. That case concerned the grant of planning permission for a bridge over a railway line. This is sometimes referred to as "the bridge to nowhere", because when viewed in isolation it served no purpose. It did not connect to any existing road or development. It was a bridge in the middle of a field. It would only begin to be used if and when housebuilders obtained planning permission for and developed a link road and housing site. The claim for judicial review had to succeed in any event because the officer's report wrongly directed the defendant's planning committee that they could take into account the benefits which would arise from the housing development anticipated but not any of the harm that that development would cause. The benefits of the additional development could not be realised without the concomitant harms. So the decision involved a failure to take into account an obviously material consideration and was irrational (grounds 1 and 2 at [32] to [69]).

80. The claimant relies upon the later part of the judgment of Andrews LJ which dealt with ground 3 at [70] to [104] and the defendant's decision that the bridge should be treated as a single project for the purposes of the EIA Directive. She held that the identification of a project is a fact-specific matter. Consequently, other cases, decided on different facts, are only relevant to the limited extent that they indicate the type of factors which might assist in determining whether a proposed development forms an integral part of a wider project.

81. Andrews LJ referred to the principle under the EIA Regulations that where EIA is required, it should generally be carried out as early as possible. As Lang J said in her second judgment in *Wingfield* [2019] EWHC 1974 (Admin) at [72]-[77] there is no objective in the Habitats Directive (92/43/EEC) requiring appropriate assessment at the earliest possible stage. Instead, the Directive focuses on the end result of avoiding damage to a European site. In the case of a "multi-stage consent" (or a multi-consent) it may be a subsequent rather than the first consent which authorises the implementation of the project (see also *No Adastral New Town Limited v Suffolk Coastal District Council* [2015] Env.L.R.28 and *R (Swire) v Canterbury City Council* [2022] J.P.L. 1026 at [94] to [95]).

82. The central flaw in the Council's decision in *Ashchurch* was its failure even to consider whether the bridge formed an integral part of a wider project for the purposes of the EIA Regulations ([82] to [84] and [96]). The court rejected the notion that in a case where the specific development for which permission is sought clearly forms an integral part of an envisaged wider future scheme, without which that development would never take place, there *can only* be a single project if the wider scheme has reached the stage where it could be the subject of an application for planning permission ([88] and see also [101]).

83. The Court then stated that the mere "difficulty" of carrying out any assessment of the impacts of a larger future project which is lacking in detail, is irrelevant

to the question whether the application under consideration forms an integral part of that larger project ([90]). *Ashchurch* was a case where it was possible to carry out some assessment of the future scheme. It was not a case where that was impossible ([91] to [92]).

84. At [102] and [104] Andrews LJ held that the fact that the EIA Regulations would require EIA to be carried out on the future wider scheme could not be conclusive on the issue of whether the earlier phase, the bridge, should be treated as a standalone project. But the Court did not suggest that this factor was altogether irrelevant and therefore must be disregarded. For example, it could be relevant to an assessment of whether the procedure being followed would have the effect of avoiding the requirements of the legislation, as in a salami-slicing case.

85. In the present case, unlike *Ashchurch*, the defendant considered whether the provision of a permanent water supply formed an integral part of the Sizewell C development and concluded that it did not. In reaching that conclusion the defendant did not take into account any irrelevant considerations.

86. The defendant did not rely upon the mere "difficulty" of carrying out an assessment of the water supply solution or the mere lack of detail on any option. Rather, WRMP24 had yet to be published in draft. NWL's solution to the water supply issue for Suffolk was unknown and would remain so until that process was completed. There was no option to assess. In any event, the defendant did not treat this factor as conclusive. Instead, it was one of a number of matters to which he had regard in the exercise of his judgment.

87. The defendant was entitled to take into account the fact that the permanent water supply had not formed part of the application for development consent and would be dealt with under a subsequent, separate process and subject to an integrated environmental assessment. He did not treat those matters as conclusive. His approach was lawful in accordance with *Wingfield* at [64] and *Ashchurch*.

88. I understand that "separate ownership" in DL 4.49, read in context, to be a reference to the separate responsibilities of SZC, for Sizewell C, and NWL, for WRMP24 and the supply of water. As the defendant noted, NWL is under a statutory duty to prepare and publish WRMP24 and SZC has no control over that process. Undoubtedly this was a relevant factor which the defendant was entitled to take into account.

89. The claimant alleges that there is functional interdependence between the Sizewell C scheme and the provision of a permanent water supply. This argument relies upon the assertion that "the need for the permanent potable water supply arose from the power station development." The implication would appear to be that there would be no such need in the absence of that development and so there is interdependence. This was not an argument which appears to have been pursued before the Panel during the Examination or subsequently before the Secretary of State. The claimant has not identified any evidence to support its assertion. Rather NWL stated that they would need to make additional water supplies available to meet the forecast demand and not just the demand from Sizewell C. The defendant had regard to NWL's

obligation to undertake WRMP24 so as to be able to meet its duties under the 1991 Act. Beyond that the defendant took into account the requirement for the permanent water supply to be available before Sizewell C can operate under a nuclear site licence.

90. I have already summarised the considerations to which the defendant had regard in deciding that the provision by NWL of additional water sources for Suffolk is not part of the Sizewell C project. There is no basis upon which the defendant's evaluative judgment can be said to be irrational.

91. The claimant's argument has much wider implications. The need for the supply of utilities such as water is common to many, if not all, forms of development. A utility company's need to make additional provision so as to be able to supply existing and new customers in the future does not mean that that provision (or its method of delivery) is to be treated as forming part of each new development which will depend upon that supply. The consequence would be that where a new supply has yet to be identified by the relevant utility company, decisions on those development projects would have to be delayed until the company is able to define and decide upon a proposal. That approach would lead to sclerosis in the planning system which it is the objective of the legislation and case law to avoid (*R (Forest of Dean (Friends of the Earth)) v Forest of Dean District Council* [2015] PTSR 1460 at [18]).

92. Lastly, in his reply Mr. Wolfe chose to focus more on the complaint that a permanent desalination plant was not treated as forming part of the Sizewell C project. He submits that SZC could have put forward a design for assessment. He claims that the absence of that information and an assessment was unlawful by virtue of *Ashchurch* at [90] and [92]. I disagree. In *Ashchurch* the bridge was only going to be constructed in order to serve the wider development in the Masterplan area. As Andrews LJ said, although it was a matter for the local authority to address on a redetermination, it was difficult to see how the bridge could not be treated as an integral part of the wider project ([100]). The unassessed wider project was a real proposal. But there is no obligation to assess a hypothetical scheme (*Preston New Road* at [75]). Here SZC considered that a permanent desalination plant was unlikely to be necessary and was not currently proposing that option. The defendant's decision that such a desalination plant was not an integral part of the Sizewell C project cannot be faulted.

93. For all these reasons ground 1 must be rejected.

Ground 2

94. On the assumption that the defendant was entitled to treat Sizewell C and the provision of a permanent water supply as separate projects, the claimant argues that the defendant acted in breach of reg.63 of the Habitats Regulations by failing to assess the cumulative impacts of both. The defendant relies upon the Panel's conclusion that even if the water supply did not form part of the project, nevertheless those cumulative effects should be assessed at the development consent stage (PR 5.11.284 to 5.11.287 and 7.5.7).

95. The claimant accepts that the adequacy of the information in an assessment is a matter for the judgment of the competent authority, the defendant, subject to a legal challenge on *Wednesbury* principles, whether under the Habitats Regulations or the EIA Regulations (*R (Champion) v North Norfolk District Council* [2015] 1 WLR 3710 at [41]; *Wingfield* at [97]; *R (Friends of the Earth Limited) v Secretary of State for Transport* [2021] PTSR 190 at [142] to [148]). The claimant submits that the defendant exercised his judgment irrationally and in breach of the principle stated in *Ashchurch* at [90] and [92] (see above). It is also suggested that the approach taken by the defendant is inconsistent with the decision in *R v Rochdale Metropolitan Borough Council ex parte Milne* [2001] Env.L.R. 22 (referred to by Andrews LJ in Ashchurch at [76] and [88]).

96. In this case the grant of development consent depended upon the IROPI test being satisfied. Mr. Wolfe submits that if assessment of the cumulative effects of power station and water supply are left to a subsequent decision, the IROPI test cannot be applied properly at that stage. By that he means that it cannot be applied in the same way as if the cumulative impacts were being assessed before the decision on whether to grant the development consent order was made. He suggests that the prior grant of the Order under the 2008 Act will make it easier for the public interest in Sizewell C going ahead to override cumulative harm or, indeed, that that would "automatically" be the outcome.

Discussion

97. It is well-established that a decision-maker may rationally reach the conclusion that the consideration of cumulative impacts from a subsequent development which is inchoate may be deferred to a later consent stage (e.g. *R (Littlewood) v Bassetlaw District Council* [2009] Env.L.R. 21; *Larkfleet* at [37]-[38]; Forest of Dean at [13] to [18]; *R (Khan) v Sutton London Borough Council* [2014] EWHC 3663 (Admin) at [121] – [134] approved in *Preston New Road* at [67] and *R (Finch) v Surrey County Council* [2022] PTSR 958 at [15(4)]).

98. In the present case the defendant referred to the possibility that new sources of water might enable a connection to be made by NWL providing a tunnel to Barsham. He accepted the assessment that that option would not give rise to additional cumulative impacts (e.g. DL 4.52). Beyond that, he decided that the new sources of water and any consequential need for a different connection were simply unknown and could not be assessed at the development consent stage. He agreed that they would instead be appropriately assessed under the WRMP process. Those judgments cannot be faulted as irrational.

99. Ground 2 is predicated upon ground 1 having failed. In other words the provision of the permanent water supply does not form part of the Sizewell C project for the purposes of the decision under challenge. On that basis the claimant's suggestion that the insufficiency of detail could have been addressed by the defendant assessing a "*Rochdale* envelope" is misconceived. *Rochdale* was concerned with the grant of outline planning permission for a project which *included* uncertain components. In any event, the claimant did not develop this submission so as to show how an "envelope" could even be defined (and then assessed) covering possible options for additional water supplies and the

connections that could be necessary, all of which would be outside the development site at Sizewell C. The suggestion was wholly unrealistic.

100. The defendant's conclusion that an assessment of the permanent water supply could not be carried out does not conflict with *Ashchurch* at [90] and [92]. Those paragraphs were concerned with whether subsequent works formed part of the current project (i.e. ground 1 of this challenge). They do not detract from the principles in the case law referred to in [97] above.

101. Mr. Wolfe made a faint attempt to rely upon the decision in *Pearce v Secretary of State for Business, Energy and Industrial Strategy* [2022] Env. L.R. 4 as requiring cumulative impacts of the permanent water supply to be assessed in the decision on whether to make the Order. The decision in *Pearce* turned on its own special facts (see e.g. [118] to [119]). The circumstances of the present case are completely different. Furthermore, in *Pearce* the promoter had been able to produce a cumulative impact assessment and the reasons given by the decision-maker for deferring consideration of that material were legally flawed. Here options for providing a permanent water supply were unknown at the time of the decision.

102. I do not think there is any merit in Mr. Wolfe's IROPI point. If a future assessment should show that the water supply option chosen would adversely affect the integrity of a European site, whether by itself or in combination with Sizewell C, IROPI would have to be applied according to the language of the Habitats Regulations and the relevant principles in the case law. It would not be appropriate to take into account the overall *benefits* of Sizewell C without also taking into account the overall *harms* of that project. The court has not been shown any authority in which deferral of the consideration of the cumulative impacts to a subsequent consent stage has caused the application of the IROPI test to be distorted or biased or watered down in some way. I note that in *Forest of Dean* Sales LJ (as he then was) stated at [19] that the earlier grants of planning permission for the original project in that case created no presumption and added no force to the contention that planning permission should subsequently be granted for the spine road that connected the two sites. The earlier permissions had not been granted on the footing that the development of those two sites was dependent upon the spine road.

103. True enough, in this case Sizewell C cannot be operated without a permanent water supply. But although the development consent has been granted in the knowledge that the power station is dependent on the future provision of a water supply, (a) it is not dependent on the provision of any particular form of supply and that is currently unknown and (b) the cumulative impact will have to be assessed properly in accordance with the legislation without any bias or distortion. The benefits of Sizewell C could not be taken into account in that future IROPI assessment without also taking into account the disbenefits. I understood Mr. Strachan KC for the defendant and Mr. Phillpot KC for SZC to adopt this analysis. They both submitted that the defendant's decision has not allowed SZC to have a "foot in the door".

104. I also note that, according to the evidence before the defendant, NWL and SZC expect a s.55 agreement to be signed in early 2024 following the WRMP process

in which the integrated environment assessment will have been carried out. It is also expected that the water supply scheme will be approved in the 2024 Price Review. Paragraph 75 of sched.19 to the Order under the 2008 Act has been drafted on that basis (see [68] above).

105. Accordingly, ground 2 must be rejected.

Ground 3

106. NE is the "nature conservation body" for the purposes of the Habitats Regulations. In this case it performed the role of providing specialist advice within its remit to the defendant as the competent authority. There is no dispute that the defendant is entitled to disagree with NE. But the claimant complains that when the defendant did so in the present case he failed to comply with the line of authority which indicates that the decision-maker is expected to give significant weight to the views of an expert body such as NE and to give "cogent reasons" for disagreeing with their views (see e.g. *R (Akester) v Department for Environment, Food and Rural Affairs* [2010] Env.L.R. 33 at [112] and *R (Wyatt) v Fareham Borough Council* [2023] Env.L.R. 14 at [9(4)]).

107. But it is important to note two additional points. First, this issue arises in the context of s.116 of the 2008 Act by which the defendant is obliged to prepare a statement of his reasons for deciding to make an order granting development consent. Even when disagreeing with the expert views of a body such a NE, the relevant standard to apply in assessing the adequacy of the reasons given is that set out in *Save Britain's Heritage v Number 1 Poultry Limited* [1991] 1 WLR 153 and *South Bucks District Council v Porter (No.2)* [2004] 1 WLR 257 (see Sales LJ in *Mordue v Secretary of State for Communities and Local Government* [2016] 1 WLR 2682 at [26] and Sir Keith Lindblom SPT in *East Quayside 12 LLP v Newcastle upon Tyne City Council* [2023] EWCA Civ 359 at [51], drawing also a parallel with *R (Mott) v Environment Agency* [2016] 1 WLR 4338 at [69] to [77]).

108. Second, the basis for the deference given to the decision of an expert body such as NE in proceedings to review their own decisions was explained more fully by Beatson LJ in *Mott* at [69] to [77]. He also stated at [64] that the court may insist upon being provided with a sufficiently clear and full explanation of the reasons for that decision as a *quid pro quo* for that deference. In my judgement similar considerations apply where a decision-maker is expected to show deference to the advice of an expert body. The level of reasoning which the law expects of a decision-maker disagreeing with the view of an expert body may depend upon whether that view is an unreasoned statement or assertion, or a conclusion which is supported by an explanation and/or evidence. It may also depend upon the nature of the subject-matter. Some advice may not call for reasoning and/or supporting evidence, other advice may do.

109. The views of NE shown to the court were sent in a submission dated 12 October 2021. They provided comments to the defendant on a Report by the Panel on the implications of the proposed development for European protected sites and species which had been submitted to the defendant. The claimant has not relied upon any other document from NE. In paragraphs 2.1.1. and 2.1.2. NE said:

> "2.1.1. It is Natural England's advice that pushing any Habitats Regulations Assessment (HRA) conclusions for integral and inextricably linked elements of the project down the line into other consenting regimes beyond the Development Consent Order (DCO) raises the likelihood that cumulative and 'in combination' impacts in these regards may get missed/ downplayed, and we wish to draw the Examining Authority's attention to this point.
>
> 2.1.2. For example, the current Water Supply Strategy proposes a mains pipeline to the site from the central/ northern Suffolk Water Resource Zone (WRZ). The environmental impacts of this pipeline have not yet been fully assessed through the HRA process. Neither have the interim solutions of a desalination plant as proposed through Change 19 [PD-050] (not considered within the RIES) and tankered water supply. Currently, the Applicant's position is 'no likely significant effects (LSE)' to any European sites from water use as stated in [REP7 -073] and summarised in paragraph 3.2.55 of the REIS. Clearly, such works could lead to a LSE on those European sites already scoped into the HRA or European sites further afield through the pipeline works, abstraction of this magnitude and other associated works to facilitate it. The water supply is a fundamental component of the eventual operation of the project, and the potential impacts of its construction should be clearly assessed in accordance with sections 4.2 and 5.15 of National Policy Statement EN-1 (NPS EN-1), sections 3.7 and 3.9 of NPS EN-6 and paragraph 3.3.9 of the Planning Inspectorate's Scoping Opinion for the Proposed Sizewell C Nuclear Development (July 2019) [APP-169]…"

110. In essence NE said no more than:

(i) The water supply is a fundamental component of the eventual operation of the project and potential impacts of its construction should be assessed with Sizewell C;

(ii) Pushing any HRA for integral and inextricably linked elements of the project down the line into other consenting regimes beyond the development consent order raises the likelihood that cumulative and in combination impacts may be missed or downplayed.

In relation to NE's comments on the pipeline connection to Barsham and the temporary desalination plant, the defendant has explained why he is satisfied with the assessment of the impacts from those elements. There is no legal challenge to that part of his decision.

111. The two bare points set out in [110] above were not so much advice as assertions without any reasoning or supporting evidence. There was no explanation as to why the water supply should be considered part of, or integral to, the project, nor any application of considerations of the kind indicated in *Wingfield.* Why

should relevant impacts be altogether missed in a subsequent assessment, any more than if assessed as part of the power station project? The same statutory regime will be applicable and NE will scrutinise the environmental information provided by NWL. Why should those impacts be downplayed without any consultee noticing, or downplayed by the decision-maker? It should not be forgotten that the water supply solution is to address a regional issue. On any view, it will be a project in its own right and the normal standards of assessment will apply to the proposal as a whole, including any connection to Saxmundham. Why should any cumulative impact of NWL's proposal not take into account cumulative impacts with Sizewell C? None of these points were addressed by NE to justify their apparent concerns.

112. I also note that, notwithstanding the national importance of the proposed project, SZC found it necessary to complain about the "unfairness" of NE having failed to attend Examination hearings to which they had been specifically invited, so that their views could be clarified and tested, in the same way as those of experts relied upon by SZC and other participants (see para. 1.3.1 of SZC's written summary of oral submissions made at ISH 15 held on 5 October 2021).

113. NE's views were summarised by the Panel in PR 5.11.284. No complaint is made about the adequacy of that summary, nor could there be. To the limited extent that NE expressed any views on this subject, they were before the defendant.

114. In my judgment the defendant did adequately explain in DL 4.65 why he disagreed with the bare assertions of NE, all the more so when that paragraph is read properly in the context of the other parts of the decision letter dealing with the same subject. The present case illustrates the inappropriateness of relying upon statements in the *Akester* line of authority as a mantra, rather than looking properly at the materials in any given case in context. Ground 3 should never have been raised by the claimant.

Ground 4

115. The defendant concluded that the project would have an adverse effect upon the integrity of the breeding marsh harrier feature of the Minsmere – Walberswick SPA arising from noise and disturbance during the construction phase (DL 5.20). Accordingly, under reg.64(1) of the Habitats Regulations the defendant had to be satisfied that there were no "alternative solutions" to the project. At DL 5.33 he did so conclude, in agreement with the Panel.

116. The claimant made representations in the Examination that there were alternative means of achieving the objective of generating electricity compatibly with the Climate Change Act 2008 which do not involve the use of nuclear power. It submits that the defendant failed to comply with the requirement in reg.64(1) to consider alternative solutions by failing to consider how that objective could be met without relying upon new nuclear power. In so far as nuclear power is considered to have particular benefits, those matters ought to have been assessed as part of a wider consideration of alternative methods of generating electricity and their respective benefits. The defendant acted unlawfully by basing his conclusion on too narrow a policy objective, namely

to provide additional nuclear power. However, if the defendant was legally entitled to adopt that approach, the claimant does not contend that he failed to assess "alternative solutions" lawfully.

117. The claimant submits that the decision-maker must consider alternative solutions which fulfil the "core policy objectives" or the "central policy objective", these being legal terms of art. They are not simply factual descriptions of a decision-maker's policy position. They fall to be identified not by the "mere election of the decision-maker", but with reference to the purpose of reg.64(1) and case law. The central policy objective should not be drawn so narrowly as to curtail the ability of the Habitats Regulations to inhibit unnecessarily harmful development in favour of less harmful alternatives. Furthermore, the phrase "alternative solutions" means that the "central policy objective" must comprise, or closely relate to, a problem "capable of solutions".

118. The claimant submits that the policy goal of providing nuclear power is "artificially limiting", to the extent that it "cannot logically be characterised as 'central'". The claimant says that, by contrast, the provision of comparatively clean energy does qualify as a central policy objective because that goes to the heart of what is sought to be achieved. Relying on its submission that the "solutions" referred to in the Habitats Regulations correspond to problems, the claimant asserts that a lack of nuclear energy is not a problem. Instead, a lack of clean energy is a problem capable of a range of alternative solutions, and so it is the provision of clean energy which qualifies as a central policy objective.

119. Lastly, the claimant suggests that the defendant erred in law by treating NPS EN-6 as determinative in deciding what were the appropriate policy objectives and alternative solutions.

Discussion

120. That last point can be rejected immediately. There is no basis for suggesting that the defendant in his decision treated the NPSs, or either of them, as conclusive on the issue of what could be considered to be relevant objectives or alternative solutions. Plainly, they were treated as "important" considerations (see e.g. DL 4.9), about which no complaint could possibly be made.

121. NPS EN-1 and EN-6 treat the need for nuclear power generation as having been demonstrated as part of the national strategy for achieving the net zero target in 2050 and ensuring diversity of supply and energy security. The Government's Energy White Paper, "Powering our Net Zero Future" (published in December 2020), announced a review of the suite of the energy NPSs but confirmed that they would not be suspended under s.11 of the 2008 Act in the meantime (DL 4.9). The White Paper includes as a "key commitment" the aim to bring at least one large-scale nuclear project to the point of Final Investment Decision by the end of the current Parliament (pp.16 and 48). The British Energy Security Supply Strategy (April 2022) states that the Government's aim is that by 2050 up to 25% of the electricity consumed in Great Britain will be generated by nuclear power, a deployment of up to 24GW (see p.197 of the defendant's HRA and DL 4.656 and 8.10).

122. The Panel accepted SZC's case that there is an urgent need for new nuclear energy generating infrastructure of the kind proposed for Sizewell C, the proposed development responds directly to that need and would make a significant contribution to low-carbon electricity generation. Furthermore, that need case accords with Government policy (see e.g. PR 5.19.1 to 5.19.18, 5.19.90 to 5.19.110, 5.19.129 to 5.19.138, 5.19.261 to 5.19.266, 6.6.4 to 6.6.5, 6.7.4, 6.7.8, 7.2.1. to 7.2.4, 7.5.4, 7.5.9 and 10.2.19).

123. The defendant's conclusions on need in the HRA and in his decision letter were based upon the Panel's assessment (see e.g. HRA at pp.189 to 190 and 196 to 201 and DL 4.1 to 4.11, 4.242, 7.1 to 7.4 and 7.13 to 7.15). The need for new nuclear power was seen as an integral part of the strategy for tackling climate change by achieving the net zero target.

124. In the same vein, the Panel rejected submissions by the claimant and others that alternative technologies should be considered and that the approach taken by SZC was too narrow (see e.g. PR 5.4.106 to 5.4.108 and 6.6). The defendant accepted those conclusions (DL 4.133 and 4.148 to 4.152 and 4.155).

125. The claimant seeks to base its approach to the identification of objectives and alternative solutions upon the judgments of the Divisional Court and the Court of Appeal in the legal challenge to the "Airports National Policy Statement" designated in June 2018 (*Spurrier* and *R (Plan B Earth) v Secretary of State for Transport* [2020] PTSR 1446).[1] But they lend no support to the claimant's case.

126. The Court of Appeal held that the standard of review in relation to both art.6(3) and art.6(4) of the Habitats Directive, and therefore reg.64 of the Habitats Regulations, is the *Wednesbury* standard ([77] to [79]). Subject to those principles, it is a matter for the decision-maker to determine the relevant objectives which need to be met and which alternative solutions would or would not meet that need.

127. At [92] and [93] the Court of Appeal addressed the problem of when objectives are defined in an unlawfully narrow manner. It endorsed the approach of the Divisional Court that an option that does not meet the core objectives of a policy statement is not an alternative solution for the purposes of reg.64(1). Such objectives must be both "genuine and critical", in the sense that a development which failed to meet those objectives would have no policy support. But it would clearly be insufficient to exclude an option simply because, in the decision-maker's view, it would meet those policy objectives to a lesser degree than the proposed or preferred option. The extent to which an option meets those policy objectives is different from an option failing to meet them at all. The judgments of the Divisional Court and the Court of Appeal provide no support for any of the additional glosses which the claimant now seeks to place on reg.64.

128. In *Plan B Earth* the objectives of the NPS under challenge were to increase airport capacity in the south east *and* to maintain the international "hub status" of the UK. The NPS rejected the option of a second runway at Gatwick as an

[1] I mention for completeness that this issue was not before the Supreme Court.

"alternative solution" to a north west runway at Heathrow because expansion at Gatwick would not enhance, rather it would threaten, the UK's hub status ([64] to [65]). The Court of Appeal held that the Secretary of State had been legally entitled to reach that conclusion ([87] to [93]). The "hub objective" had been one of the "central", or "essential", or "genuine and critical", objectives of the policy. That objective had not been constructed with deliberate and unlawful narrowness so as to exclude other options improperly.

129. The objectives of EN-1 and EN-6 include the generation of clean energy but the central or essential objectives of those policies is not limited to that aim. They also include diversity of methods of generation and security of supply. The Government sees new nuclear power as an essential component of those objectives, just as wind and solar power. That has remained the Government's policy in its recent statements (see also [28] to [32] above). Accordingly, there can be no legal challenge to the approach taken by the Panel and by the defendant which excluded alternative technologies as alternative solutions. In the light of the Court of Appeal's decision in *Plan B Earth* the legal position is crystal clear.

130. The claimant's argument depends upon an illegitimate attempt to rewrite the Government's policy aims by pretending that the central policy objective is at a higher level of abstraction, namely to produce clean energy, without any regard to diversity of energy sources and security of supply. But it is not the role of a claimant, or of the court, to rewrite Government policy, or to airbrush objectives of that policy which are plainly of "central" or "core" or "essential" importance.

131. The absurdity of the claimant's argument was well-demonstrated by Mr. Strachan KC and by Mr. Phillpot KC for the defendant and SZC respectively. The implication of ground 4 would be that a decision-maker dealing with a proposal for a solar farm or wind turbine array, obliged to comply with reg.64(1), would have to consider as alternative solutions nuclear power and, as the case may be, wind power or solar power options, But in my judgment there is nothing artificial or unlawfully limiting about a Government policy which identifies as core objectives the need to provide a mix of new electricity generation technologies, comprising solar, wind and nuclear power. Indeed, in para. 9.1.1 of the HRA the defendant noted a decision of the CJEU that the objective of ensuring security of supply may constitute IROPI.

132. For these reasons, ground 4 must be rejected. In my order providing for a rolled up hearing, I directed the claimant to review the legal merits of its various grounds, taking as an example its failure to address (a) the content of the Government's policy on nuclear power as part of a mix of energy sources and (b) the decision in *Plan B Earth*. The claimant should have abandoned ground 4, but chose instead, in effect, to try to continue its challenge to the merits of Government policy through the means of judicial review. The use of the court's process in that way is wholly inappropriate.

Ground 5

133. The claimant submits that when the defendant carried out his IROPI assessment he took into account a legally irrelevant consideration and/or one which was

"unevidenced", namely that the project would contribute to achieving the objective of reducing GHG emissions by 78% by 2035 from the UK's 1990 baseline (para. 74 of skeleton).

134. I interpose to make one point straight away. The claimant's two propositions cannot both be correct. Either a consideration is irrelevant or it is not. If it is, then it does not matter whether any evidence was before the decision-maker on the point. Not surprisingly, it turns out that the claimant does not really contend that this consideration is incapable of being relevant. Instead, the complaint is that the defendant drew a conclusion which was unsupported, or "insufficiently" supported, by evidence (skeleton paras. 76 and 80 to 81).

135. The claimant points out that, according to SZC's Construction Method Statement, it is expected that the first of the two reactors would be operational at the end of 2033 and the second by mid-2034. But that depends upon a number of assumptions, including the provision of a permanent potable water supply before the power station can be operated. The claimant submits that there was no evidence that that water supply would be implemented before 2035. It is said that SZC's expectation does not take into account uncertainty and delay in resolving that issue (paras. 75 to 76 of skeleton). The claimant complains about the absence of a timeline for the provision of the water supply and of evidence as to the degree of contribution Sizewell C would make to "the 2035 target". These are said to have been "obviously material considerations", applying the irrationality test laid down by the Supreme Court in the *Friends of the Earth* case. But ultimately, the criticism that the contribution to reducing GHG emissions by 2035 was not estimated comes down to an allegation that the timescale for determining and providing a permanent potable water solution was unclear (para. 85 of skeleton).

136. The claimant also submits that the defendant could not maintain that there was insufficient information about the eventual water supply to assess its environmental impacts (under ground 2) and at the same time rely upon the environmental benefits of Sizewell C where its operation is dependent upon that supply.

Discussion

137. A reduction in GHG emissions by 78% by 2035 relates to the Sixth Carbon Budget ("CB6") which was set under the Climate Change Act 2008 by the Carbon Budget Order 2021 (SI 2021 No. 750). It requires the UK's net carbon account not to exceed 965 Mt CO_2e over the period 2033-2037 (see *R (Friends of the Earth Limited) v Secretary of State for Business, Energy and Industrial Strategy* [2023] 1 WLR 225 at [2] to [12]). This is said to equate to a reduction in GHG emissions from the 1990 baseline by 78% by 2035.

138. Initially the claimant's argument was a little difficult to follow because the main sources upon which it relied in the Statement of Facts and Ground and its skeleton do not address the 78% target. Instead, it referred to the IROPI case for Sizewell C, which was based upon the national importance and urgent need for new nuclear power generation, including:

(i) The continuing growth in the UK's electricity demand, the retirement of existing electricity capacity and "a generation shortfall of 95GW by 2035".

(ii) The UK's commitment to reducing GHG emissions to net zero by 2050 (page 195 of the defendant's HRA and see also paras. 8.1, 8.3.4 and 8.3.5).

Similarly, the HRA rejected alternatives which would involve a significant delay to the construction programme, because Sizewell C would not contribute to addressing the shortfall in generation capacity of 95GW in 2035.

139. Likewise, the Panel had referred in its Report to the 95GW shortfall in 2035 and the contribution which Sizewell C could make (PR 6.6.4 and 6.7.4). But Mr Bowes showed how that issue was linked to the CB6 target, relying upon PR 5.19.137. That explained that in a report by the Climate Change Committee making recommendations for the sixth carbon budget, the "Balanced Net Zero Pathway", which they treated as a central scenario, assumed that it would be necessary for the power sector to reach zero emissions by 2035, or to decarbonise completely.

140. The defendant and SZC sought to argue that the focus of the decision letter was on the net zero target for 2050 rather than any 2035 target along the way. But I do not agree. The Panel's conclusions took into account the contribution that Sizewell C could make to meeting a shortfall in generating capacity by 2035 and not simply the net zero target for 2050. Although one part of the decision letter referred in broad terms to the contribution of Sizewell C to limiting climate change in accordance with the objectives of the Paris Agreement (DL 5.35), other parts rely upon the Panel's Report at PR 7.5.4 (i.e. DL 7.3). PR 7.5.4 was based in turn upon the detailed assessment in PR 5.19. That section of the Report relied upon the urgent need for new nuclear power to contribute to electricity generation by 2035 (see e.g. PR 5.19.78, 5.19.136 to 5.19.137 and 5.19.163).

141. Furthermore, the defendant's decision also took into account his HRA. In that document he decided that the IROPI test was satisfied, basing himself upon the policy context for the project, its benefits as presented by SZC and the UK's commitment to decarbonising the electricity sector by 2035 (pp.195-6). In his overall conclusion on IROPI the defendant also relied upon section 6.7 of the Panel's Report which, as we have seen, was based upon section 5.19 of that document. Accordingly, it cannot be said that the project's claimed contribution to addressing the shortfall in 2035 in electricity generation did not materially influence the defendant's decision on the application of the Habitats Regulations as well as his decision to grant development consent. That leaves the gravamen of the claimant's complaint, namely the claimed lack of evidential support for the Secretary of State's view that the project would make such a contribution by 2035.

142. I have previously summarised under ground 1 much of the material before the Examination and the defendant on the steps which NWL and SZC stated would

be followed in relation to WRMP24 so that NWL will comply with its duties under ss. 37, 37A and 37B.

143. In a statement of common ground between NWL and SZC dated 8 October 2021, NWL acknowledged that 2032 had been identified by SZC in discussion as "the backstop date" for the permanent water supply to be "fully available". The Panel referred to this date in its Report (PR 5.11.283).

144. In its letter to the defendant dated 23 February 2022 NWL confirmed that the water demand figures for the operational phase of Sizewell C had been included in WRMP24 from 2032 and that new schemes would be required in that Plan to meet all the forecast demand in the Suffolk supply area, including that of the project. NWL reiterated its commitment to providing the supply required for Sizewell C. That would be reliant upon the finalisation of new supply schemes and their identification in WRMP24, the completion of a s.55 agreement under the 1991 Act and "the costs approval process". The defendant was informed that the draft WRMP would be submitted to Defra by October 2022.

145. The position of both NWL and SZC was that after the submission of the draft WRMP for statutory consultation, they would work together from October 2022 to negotiate an agreement under s.55, which would include funding for the design and delivery of any infrastructure specific to Sizewell C.

146. SZC pointed out that the WRMP24 would be subject to a fully integrated environmental appraisal, including SEA and, where necessary, HRA. That would involve consultation with *inter alia* NE. The final version of the plan would have to be compliant with the Habitats Regulations and by definition that would have to precede the installation of a permanent water supply. I also note that the defendant has already stated in his decision letter that he is satisfied with the assessment of the Barsham transfer pipeline if that connection should be chosen.

147. The provision of a *temporary* supply by SZC (which has been assessed in the process under the 2008 Act and is not itself the subject of legal challenge) gives NWL 10 years within which to provide a permanent solution. In addition, SZC indicated (in para. 2.2.5 of its response dated 8 April 2022) that, subject to detailed assessment, the lifespan of the temporary desalination plant could be extended for a short period after the end of the construction phase, if necessary.

148. Subsequently, SZC informed the defendant that an agreement with NWL under s.55 and/or s.56 of the 1991 Act would be likely to be ready to be signed once NWL's Business Plan had been approved by OFWAT most likely in 2024. There was no reason to suppose that a new water supply scheme for a critical NSIP would not be approved in the 2024 Price Review.

149. This material was carefully summarised in the decision letter (DL 4.12 to 4.42). The weight to be given to it was a matter for the defendant. He concluded that there was a reasonable level of certainty that a permanent water supply solution can be found before the first reactor is commissioned (DL 4.44). He was satisfied on the basis of the information supplied on the WRMP process under

the 1991 Act that "there is a requisite degree of confidence that a long-term solution is deliverable" (DL 4.64).

150. In my judgment the material before the defendant was legally adequate to entitle him to reach those conclusions. It is impossible to say that his judgment on such an evaluative subject looking into the future was irrational. Once that position is reached, there is no legal reason why the defendant could not take into account the contribution which Sizewell C is expected to make to reducing the shortfall in electricity generation in 2035 (or to the target for reducing GHGs).

151. Lastly, there is no internal contradiction in the decision letter between the approach taken by the defendant to the assessment of cumulative effects arising from the permanent water supply for Sizewell C and his reliance upon environmental benefits which are dependent upon the provision of that supply. As to the former, the defendant decided that there was no option under the WRMP24 process which could be assessed at the stage when the decision letter was issued. As to the latter, the defendant was sufficiently confident that a solution would be found through the WRMP24 process (after having been subject to environmental assessment) and then completed before the operation of the power station is expected to begin in 2033. It is therefore apparent from the decision letter that there is no inconsistency in the defendant's reasoning or lack of coherence. The two conclusions are self-evidently compatible.

152. For all these reasons, ground 5 must be rejected.

Ground 6

153. The claimant submits that the defendant acted irrationally in concluding that the Sizewell C site would be clear of nuclear material by 2140 and/or failed to give legally adequate reasons for rejecting the claimant's case on this subject. Inadequacy of reasoning depends upon the claimant showing a lacuna in the decision raising a substantial doubt as to whether it was tainted by a public law error (see *Save* and *South Bucks*).

154. The Panel noted that it is a requirement of Government policy that spent fuel be stored on a new nuclear site such as Sizewell C until a UK Geological Disposal Facility ("GDF") becomes available (PR 5.20.57 and 5.20.97). NPS EN-6 states that the key factors in determining the duration of on-site storage are the availability of a GDF and the time needed for spent fuel to cool sufficiently for disposal in a GDF (PR 5.20.96.).

155. The claimant submits that the defendant was aware of an estimate provided by SZC that a GDF would not be available to accept spent fuel from a new build project until 2145. Furthermore, during the Examination the claimant had relied upon information provided by the ONR in relation to Hinkley Point C which, according to the claimant, suggested that spent fuel would need to be kept at the Sizewell C site until about 2165.

156. The claimant submits that it was irrational for the defendant to proceed on the basis that spent fuel would be removed from the site by 2140. The modelling of future sea levels, storm events and the adequacy of the coastal defences only ran

to 2140. It was irrational for the defendant not to engage with the risk of the site being flooded from the sea while spent fuel remains on site after 2140 and before the site is decontaminated.

Discussion

157. It is well-established that an enhanced margin of appreciation is to be afforded to a decision-maker relying on scientific, technical and predictive assessments (*Mott* at [69] to [78]). Plainly that principle is engaged when dealing with the evaluation of predictions far into the future about such matters as the effects of climate change on sea levels, the availability of a GDF and the life span and decommissioning of a project such as Sizewell C. It is also clear that a decision-maker deciding whether to grant development consent for such a project does so in the context of a range of statutory regimes which address changes in circumstance (and predictions) as they occur during the remainder of this century and well into the next. Those regimes are obviously material considerations.

158. SZC stated in the Examination that for the purposes of the EIA of the project it is assumed that the operation of the power station will end in the 2090s and by 2140 the interim spent fuel store will have been decommissioned (PR 5.20.19 to 5.20.20). Under its nuclear site licence SZC is required to demonstrate that the on-site facilities for interim storage of spent fuel can be designed, operated and decommissioned in a safe manner that ensures any risks to *inter alia* the environment are suitably and sufficiently controlled, including risks from flooding (PR 5.20.55). At PR 5.20.104 the Panel noted that Suffolk County Council and East Suffolk Council had raised no concerns regarding radioactive waste and said that that was to be expected because ONR would regulate on-site radioactive waste management and the EA would regulate gaseous and aqueous emissions.

159. The Panel summarised objections to the modelling work made by the claimant (e.g. at PR 5.20.59).

160. The Panel referred to the Government's firm policy commitment to the GDF for the long-term storage of high-level radioactive waste, in order to meet the UK's international obligations (PR 5.20.123 to 5.20.125). SZC's assumptions regarding on-site storage of spent fuel had been based upon there being a GDF available for transfer in the long term. The Panel considered that to be a reasonable assumption (PR 5.20.130), although it acknowledged that there was a degree of uncertainty in relation to the timing of the GDF (PR 5.20.131). The Panel reached the judgment that there was sufficient evidence to be able to conclude that the policy tests for the handling of the waste were met, taking into account SZC's statement that spent fuel would be removed from Sizewell C by 2140 (PR 5.20.133 to 5.20 134). They said that this issue should not weigh against the making of the Order (PR 7.4.195 to 7.4.202).

161. On 7 August 2020 the ONR had provided information in an email which responded to questions sent to them by the claimant on 15 June 2020. Those questions covered a range of issues. One question asked ONR whether, in the light of a comment made by the Nuclear Decommissioning Agency (NDA), the

spent fuel from Sizewell C would not be accepted at the GDF until about 140 years from the end of operations, and so would have to remain on site for about 200 years from start up. ONR responded that they did not have information on this subject in relation to Sizewell C. But for Hinkley Point C their understanding was that:

(i) The cooling period was dependent upon the burn-up rate assumed for the fuel used in a reactor. The NDA had used a maximum peak burn-up rate and had not taken into account a number of aspects of the strategy for Hinkley Point C. The average burn-up for spent fuel at that power station would be lower than the NDA had assumed and would therefore have a lower heat output;

(ii) The thermal output of a dry disposal canister containing four spent fuel assemblies is dependent upon a mixing strategy which combines high and low burn-up fuel assemblies within a single cannister;

(iii) An analysis had shown that a storage period of 55-60 years after the end of operation would be needed to meet the assumed GDF thermal limits for disposal for all fuel assemblies, using the strategy for Hinkley Point C;

(iv) Accordingly, on the assumption that generation at Hinkley Point C begins in 2025 and ends in 2085, that fuel would be sufficiently cool to transfer to the GDF in 2140-2145. Assuming that it takes just over 9 years to remove fuel to the GDF, all fuel would be transferred from Hinkley Point C by between 2150 and 2155, which would determine the end of use of the fuel stores at that site.

The ONR also stated that the "assumed availability date for the GDF" to accept fuel from new reactors is around 2130, which is earlier than the date relied upon by the claimant taken from a document produced by SZC (see [155] above).

162. The ONR's response also stated that if there were to be a subsequent acceleration in the effects of climate change, so that the impacts were greater or more rapid than currently predicted, that would involve timescales of several decades, so that monitoring would be able to inform decisions under the conditions of the nuclear site licence on the protective measures required. "Managed adaptive options", such as an increase in the height of a coastal defence, with trigger points, would ensure that the site remains safe under the terms of the nuclear site licence.

163. In its representations to the Panel dated 24 September 2021 the claimant relied upon the email from the ONR and submitted that, assuming Sizewell C begins operation in 2035 and ceases to operate in 2095, a 60-year cooling period would end in 2155 and the removal of spent fuel off site would take until 2165.

164. In its representations to the Panel in September 2021 after ISH 11, SZC stated that the Fourth Addendum to the Environmental Statement for the project assumed that Sizewell C would cease to operate in the 2090s, the fuel store will have been decommissioned by "the 2140s" and 2190 was "the theoretical

maximum site lifetime". An EIA for decommissioning would be required in the years leading up to the end of electricity generation (paras. 1.11.1 to 1.11.2 on p.14).

165. An Addendum to the Flood Risk Assessment for the main development site, produced by SZC in January 2021, had increased the height of the proposed "hard coastal defence feature" to 14.6m above Ordnance Datum. Updated modelling was said to show that this would be sufficient to protect the site against events up to 2190 under reasonably foreseeable climate change scenarios. More extreme events are to be dealt with in SZC's safety case which will be assessed by the ONR (para. 1.36 of the Flood Risk Assessment and the Panel's Report at PR 5.8.91).

166. The issues concerning the adequacy of coastal defence proposals and long-term flood risks impact not only on-site radiological waste management but also a number of other subjects. The issues were considered by the Panel in some detail in a number of sections of their report, such as sections 5.7, 5.8 and 5.20. The Panel's Report has an interlocking structure and needs to be read as whole. The Panel was well aware of the objections on this point raised by the claimant and by other participants, such as Professor Blowers. The Report provided a good summary of the material submitted, including that provided by SZC (e.g. PR 5.7.35 to 5.7.40, 5.8.252 and 5.8.259 to 5.8.260, 5.8.276, 5.8.295 to 5.8.296, 5.20.6, 5.20.18 to 5.20.20, 5.20.59 and 5.20.98). In several places in its Report the Panel expressed satisfaction with *inter alia* the "adaptive design" for the proposed coastal defences, the monitoring of future sea levels through the Coastal Processes Monitoring and Mitigation Plan ("CPMMP") and future modifications of the design through the controls exercisable by the ONR and EA (e.g. 5.8.97, 5.8.99, 5.8.231, 5.8.239, 5.8.259 to 5.8.260, 5.8.299, 5.8.315 to 5.8.320, 5.20.98 to 5.20.102). At PR 5.8.313 the Panel noted that the design parameters of the sea defences would be secured by Requirement 19 of the development consent.

167. Participants continued to make representations after the close of the Examination. For example, a Mr. Parker returned to the subject of the lifetime and adequacy of the sea defences at Sizewell C. The EA and ONR provided a joint response dated 7 June 2022 which was forwarded to the defendant. At DL 4.366 the Secretary of State relied upon this response which he had summarised at DL 4.365:

> "4.365 The Secretary of State notes the post-Examination representations submitted by IPs related to flood risk, including Mr Bill Parker who raised concerns regarding the protection from flooding during operation, decommissioning and the residual time spent fuel is stored on site. The Secretary of State notes the EA's letter to Mr Bill Parker of 7 June 2022 which confirmed that the FRA extended to 2190, and that for the Reasonably Foreseeable actual risk up to 2190, there would be no inundation of the main platform or SSSI crossing from overtopping of the HCDF or the remaining lower northern and southern sand dunes/shingle defences in all events up to the 0.1% annual probability flood events in 2019. The EA's letter also

> included a subsection titled 'ONR' response, confirming that during the operation of a nuclear licenced site, it is a regulatory expectation for the licensee to periodically review the validity of the safety case for all facilities on site against external hazards, to ensure the site remains protected, including the dry fuel store and taking updated climate change projections into account for coastal flood hazard."

The ONR specifically said that the design of the sea defences had been based upon the period running up to 2140, but if the life-time of the station extended beyond that year, SZC would need to demonstrate that the sea defences will continue to protect the site adequately, and if not provide additional protection.

168. In DL 4.250 the defendant agreed with the conclusions of the Panel summarised in DL 4.244 to DL 4.248. In DL 4.295 he expressed satisfaction with the modelling of sea level rises to 2140 for reasonably foreseeable events, including up to the 1 in 10,000 year event and in DL 4.246 with the adaptive design to provide a feasible means of increasing the crest height of the Hard Coastal Defence Feature to cope with a "credible maximum sea level rise". The defendant also relied upon further work carried out by SZC and the EA after the close of the Examination which had resolved all of the Agency's outstanding concerns at that stage. The defendant was also satisfied that matters such as the monitoring of climate change and adaptive measures would be adequately addressed by the ONR through the nuclear site licensing regime (DL 4.235 to DL 4.241, 4.247 and 4.250).

169. The defendant returned to these issues at DL 4.279 which summarised the Panel's views as follows:

> "4.279 The ExA considers [ER 5.8.232 et seq.] the adequacy of the proposed climate change adaptation measures and the resilience of the Proposed Development to ongoing and potential future coastal change during its operational life and any decommissioning period including the scope for the HCDF to undergo design adaptation to maintain nuclear safety against predicted sea level rises. The Sizewell Coastal Defences Design Report [REP8-096] provides a design description of the HCDF Adaptive Design at section 3.11 and is designed to protect the Proposed Development from a 1 in 10,000 year storm event with reasonably foreseeable ("RF") climate change effects up to the end of its design life in 2140. The ExA consider that the Applicant recognises that, given the inherently uncertain nature of climate change, the RF climate change scenario may be exceeded. ONR and EA guidance requires that the sea defence be capable of adaptation to a credible maximum sea level rise [ER 5.8.252]. The sea defences have therefore been designed to allow for future adaptation to accommodate the credible maximum scenario, should it develop. The Adaptive Design would provide a simple means of increasing the crest height of the HCDF to reach a crest level of 16.4m OD [ER 5.8.252]. The implementation of measures to enact the Adaptive Design would

> be driven by progressively observed effects of climate change, specifically mean sea level rise. The MDS FRA [AS-018] confirms that the impacts of climate change on sea level rise would be monitored and assessed at set intervals to determine the trajectory of the projections, and consider whether there is any change from either the current considered projections or the climate change guidance as applied in the application [ER 5.8.253]. A number of issues were raised by IPs in relation to Adaptive design and its implementation [ER 5.8.254 et seq.]. Having considered the submissions and responses from the Applicant [ER 5.8.252 et seq.] the ExA takes the view that as indicated in relation to the SMP, and having regard to the details and explanation provided by the Applicant, that the HCDF, including the Adapted Design, would be positioned as landward as possible. In addition, the requirement 19 in the Order would provide a means whereby the design details of various aspects of the HCDF would require ESC approval in consultation with the MMO and the EA before commencement of that work. The ExA considers that this would provide an appropriate safeguard at detailed design stage in relation to matters relating to layout, scale and external appearance of the HCDF, and its integration with other marine infrastructure [ER 5.8.256]."

The defendant agreed (DL 4.293) (and see also DL 4.280, 4.284, 4.285 and DL 4.290).

170. DL 4.261 referred to the Fourth Addendum to the Environmental Statement (see [164] above) and additional modelling work carried out during the Examination. DL 4.266 referred to the suitability of the CPMMP to provide controls in the future for coastal defence. Certain extreme events are to be left to regulation by the ONR (DL 4.267).

171. The decision letter began to deal with radiological issues at DL 4.583 and in that context it returned to the subject of climate change, sea levels and the safe storage of fuel rods. The defendant summarised the views of the Panel at DL 4.589 to DL 4.597. At DL 4.598 the defendant agreed with the Panel's conclusions and referred to the further information on coastal defence modelling and the requirement for a nuclear site licence.

172. The claimant relied upon DL 4.590 which states:

> "The issues of coastal defences, and the impact of climate change on the modelling for the safety of those defences, were considered by the ExA in section 5.8 and section 5.7 of the ExA Report respectively. The ExA considers [ER 5.20.101] that the coastal defences have been designed so they can be modified if it is necessary to do so, with the monitoring of the sea levels secured through the CPMMP, and this is further reinforced by the obligations required by the NSL regime regulated by the ONR and the permits regulated by the EA. The ExA is persuaded [ER 5.20.102] that the Applicant's conclusions are predicated on

> the basis that the site will be clear of nuclear material by 2140, the period which has been modelled for coastal defences, and under these circumstances the ExA consider the tests set out in paragraph 2.11.5 of NPS EN-6 would be met."

The claimant places a good deal of emphasis on the last sentence, and also upon DL 4.245. These paragraphs refer to an assumption that spent fuel will be removed from Sizewell C by 2140, which is also the year to which the modelling for predicted extreme sea levels runs.

173. The claimant complained that the defendant failed to give reasons addressing its reliance upon the ONR's email dated 7 August 2020. In my judgment he was under no legal obligation to do so. The limitations of that material produced in 2020 were obvious on the face of the document itself, without there being any need for the Panel or the defendant to spell that out by simply repeating them. The comments by the ONR related to the Hinkley Point C project in the absence of information on Sizewell C. They were not of any real significance. Naturally the Panel and the defendant would focus on later material produced in 2022 which specifically related to the Sizewell C project (see e.g. [167] above). An application for a nuclear site licence for that scheme had yet to be submitted. SZC said to the Examination that the fuel store would be decommissioned by the 2140s, that is not necessarily by 2140 (DL 4.252). Although the ONR had estimated in 2020 that the GDF would be available by 2130, the claimant relies upon an alternative prediction, 2145, emanating from SZC. The Panel stated that it was reasonable to assume that storage would be available in a GDF in the long term, but added, not surprisingly, that there is a degree of uncertainty (PR 5.20.131), referring no doubt to timing.

174. It is obvious that the issue of how far into the next century spent fuel will need to remain at Sizewell C is subject to uncertainty. But that is not the only uncertainty about the future. The ONR, EA, SZC and others have addressed the possibility that climate change may cause sea levels to increase more quickly. Estimates about the availability of facilities and projections are having to be made an unusually long way into the future. On any fair reading of the Panel's Report and the decision letter, that uncertainty was recognised. I agree with counsel for the defendant and for SZC that what matters is how that subject was addressed.

175. The claimant's ground 6 is a classic example of a failure to read the decision letter fairly and as a whole. It is plain that in DL 4.590 the defendant also relied upon the adaptive nature of the design for the coastal defences, the monitoring of sea levels through the CPMMP and the controls which will be applied by the ONR and the EA through their respective regulatory regimes. That paragraph has to be read in the context of the many passages in the Panel's Report and in the decision letter where those matters were explained and relied upon. The suggestion by the claimant's counsel that the defendant did not rely upon those matters when addressing the future adequacy of coastal defences in relation to the storage of spent fuel is wholly untenable. The point was made clear in relation to the ONR and the nuclear site licence, for example in DL 4.365. The defendant relied, as he was entitled to do, upon the normal assumption that those

other regulatory regimes will be operated properly. The defendant's reasoning cannot be treated as irrational or legally inadequate.

176. In addition, Requirement 19 of the development consent requires details of coastal defence features to be submitted and approved by the local planning authority, before construction of those works may commence, which must include a monitoring and adaptive sea defence plan that sets out periodic monitoring proposals and the trigger point for when the crest height of the sea defence would need to be increased to 16.9m above Ordnance Datum.

177. Accordingly, ground 6 must be rejected. In reaching that conclusion, I have not found it necessary to consider the application of s.31(2A) or (3C) and (3D) of the Senior Court Act 1981.

Ground 7

178. This ground is concerned with GHG emissions from the operation of Sizewell C. The claimant refers to DL 4.248 and DL 4.250 in which the defendant agreed with the Panel that "emissions of the magnitude demonstrated would not have a significant effect on the UK's ability to meet its carbon budget commitments or the ability of the Government to meet the UK's obligations under the Paris Agreement". The claimant then says that that conclusion is inconsistent with this part of DL 8.9:

> "Operational emissions will be addressed in a managed, economy-wide manner, to ensure consistency with carbon budgets, net zero and our international climate commitments. The Secretary of State does not, therefore need to assess individual applications for planning consent against operational carbon emissions and their contribution to carbon budgets, net zero and our international climate commitments."

179. The claimant submits firstly, that DL 8.9 should be read as meaning that the defendant has made no assessment of the contribution of *operational* GHG emissions to the carbon budgets and secondly, there was no evidential basis upon which he could conclude in DL 4.248 and DL 4.250 that operational emissions from Sizewell C would not have a significant effect on the UK's ability to meet its climate change obligations (skeleton paras. 106 to 110).

Discussion

180. DL 8.9 appears in section 8 of the decision letter which is entitled "Other Matters". Under that heading DL 8.8 to DL 8.9 refer to the Climate Change Act 2008 and the Net Zero Target in broad terms. The context for the part of DL 8.9 which the claimant quotes is set by the opening two sentences to which it did not refer. Thus, the context is the continuing significance of the NPSs and the need for nuclear generation of the kind represented by Sizewell C in accordance with those policy statements.

181. EN-1 states that carbon emissions from a new nuclear power station are likely to be much less than from a fossil fuelled plant (para. 3.5.5.). New nuclear power

forms one of the three key elements of the Government's strategy for moving towards a decarbonised, diverse electricity sector by 2050, along with *inter alia* renewable electricity generation (para. 3.5.6 and see also para 3.5.10). I agree with the defendant and SZC that the part of DL 8.9 which the claimant seeks to criticise is entirely consistent with para 5.2.2 of EN-1 which states:

> "5.2.2. CO_2 emissions are a significant adverse impact from some types of energy infrastructure which cannot be totally avoided (even with full deployment of CCS technology). However, given the characteristics of these and other technologies, as noted in Part 3 of this NPS, and the range of non-planning policies aimed at decarbonising electricity generation such as EU ETS (see Section 2.2 above), Government has determined that CO_2 emissions are not reasons to prohibit the consenting of projects which use these technologies or to impose more restrictions on them in the planning policy framework than are set out in the energy NPSs (e.g. the CCR and, for coal, CCS requirements). Any ES on air emissions will include an assessment of CO_2 emissions, but the policies set out in Section 2, including the EU ETS, apply to these emissions. The IPC does not, therefore need to assess individual applications in terms of carbon emissions against carbon budgets and this section does not address CO_2 emissions or any Emissions Performance Standard that may apply to plant."

182. Section 4 of the decision letter is entitled "Matters considered by the ExA [the Panel] during the Examination." DL 4.232 to DL 4.250 dealt with climate change and resilience. Within that part DL 4.242 to DL 4.243 addressed GHG emissions and the carbon footprint. DL 4.244 to DL 4.250 summarised the Panel's overall conclusions on various climate change issues and stated that the defendant agreed with the Panel on those matters.

183. DL 4.242 and DL 4.248 referred back to the parts of the Panel's Report which summarised the quantitative analysis before the Examination, the responses of other parties to that material, and the Panel's conclusions at PR 5.7.56 to PR 5.7.100. That summary covered the quantitative analysis in the ES and in the subsequent Life Cycle Analysis carried out for SZC.

184. At PR 5.7.90 the Panel concluded:

> "The ExA concludes that the ES [APP-342], as updated by [AS-181, REP2-110], and [REP10-152], demonstrates that construction emissions from the Proposed Development would be less than 1% of the UK Government's carbon budget for the relevant period, and would not be significant in accordance with the criteria as described in Chapter 26 [APP-342]. The ExA is therefore content that those emissions would not materially affect the ability of the Government to meet the UK's obligations under the Paris Agreement. Similarly, the gross emissions associated with the operational phase have been found to be less than 1% of relevant periods in which they arise. The ExA also

> recognises the support provided by national policy for low carbon power generation projects such as the Proposed Development, and that the importance for the UK's carbon budgets should also be considered from the perspective of the carbon emissions that would otherwise be produced by other sources, if they were not generating. The national policy support for such low carbon generation projects has been considered in detail in section 5.19 of this Report."

That conclusion was then carried forward to PR 5.7.100. It is also relevant to note the reference here to the policy support for new nuclear power generation because of the contribution it makes to reducing GHGs that would otherwise be produced from other sources (as opposed to the "gross" emissions from a nuclear power station taken in isolation).

185. The defendant's decision letter accepted both PR 5.7.90 and PR 5.7.100. There was therefore ample quantitative material to support the conclusions of the Panel and, in turn, the Secretary of State. Mr. Wolfe KC relies once again upon a dictum in *R (Association of Independent Meat Suppliers) v Food Standards Agency* [2019] PTSR 1443 at [8]. But for the reasons set out in *R (Goesa Limited) v Eastleigh Borough Council* [2022] PTSR 1473 at [19] that passage does not alter the well-known *Wednesbury* principles applied by the Courts (see also *R (Law Society) v Lord Chancellor* [2019] 1 WLR 1649 at 98]).

186. The claimant then complains that there is no evidence that the defendant personally considered the quantitative assessment carried out for SZC, whether in the ES or the Life Cycle Assessment. This is yet another attempt to rely upon part of the judgment of Sedley LJ in *R (National Association of Health Stores) v Secretary of State for Health* [2005] EWCA Civ 154 without reading the relevant passages as a whole. The High Court has analysed the principles in *R (Transport Action Network Limited) v Secretary of State for Transport* [2022] PTSR 31 at [60] to [73] and *R (Save Stonehenge World Heritage Site Limited*) *v Secretary of State for Transport* [2020] PTSR 74 at [62] to [66] and [178]. A Minister is entitled to rely upon a summary prepared by his officials of the material which his department has received. The issue is therefore the narrower one of whether there are any grounds for criticising the legal adequacy of that summary in the context of ministerial decision-making. In my judgment the Secretary of State was not required himself to delve into the ES or the Life Cycle Assessment in the way the claimant suggests. The summary provided in the Panel's Report and in the draft decision letter, both of which were provided to the defendant for him to consider, were as, a matter of law, perfectly adequate.

187. Ground 7 is utterly hopeless and must be rejected.

Conclusions

188. The court is faced with a similar situation to that which arose in the Heathrow litigation where, having heard full submissions in a rolled-up hearing (in that case dealing with five different claims), it had to decide whether permission to apply for judicial review should be granted on each ground (*Spurrier* at [667]). In the present case as in *Spurrier*, the mere fact that the court has had to consider

in a rolled-up hearing, and in a judgment, a substantial amount of material and legal submissions, does not mean that the grounds raised pass the threshold for arguability.

189. I consider that each of grounds 3 to 7 is totally without merit (CPR 23.12). Accordingly, permission must be refused in relation to those grounds.

190. In relation to grounds 1 and 2 I conclude that both are unarguable and permission should be refused.

191. The application for permission to apply for judicial review is dismissed.

Annex: Paragraphs 4.43 – 4.69 of the Secretary of State's Decision Letter

The Secretary of State's Consideration of Water Supply

4.43 The Secretary of State has considered the supply of water during the construction period. He is satisfied with the Applicant's assurance that potable water will be supplied via a combination of tankers and a temporary desalination plant. The Secretary of State notes that the Applicant reaffirmed its commitments in the Water Supply Strategy for supply of non-potable water throughout the construction period. The Secretary of State is satisfied that there will be an adequate supply of both potable and non-potable water during the construction period and that the impacts of the water supply during the construction period have been properly assessed as part of this application and where relevant are considered elsewhere in this letter.

4.44 The Secretary of State has considered the Applicant's response to his questions on the matter of long-term water supply, as well as the comments submitted by IPs on this matter in light of the ExA's report. The Secretary of State notes that paragraph 8 of the letter from Walker Morris on behalf of NWL, of 23 February 2022, provides that, in addition to demand management options, NWL is also appraising other options that include (but are not limited to): an import from Anglian Water; nitrate removal at Barsham WTWs; effluent reuse and desalination; and longer term (post-2035) winter storage reservoirs. The Secretary of State considers that these represent potentially viable solutions for the water supply strategy as would the fall back of the Applicant's own permanent desalination plant if those solutions cannot be used. The Secretary of State is therefore content that if consent is granted for the development, there is a reasonable level of certainty that a permanent water supply solution can be found before the first reactor is commissioned.

4.45 With regard to the Applicant's case that the permanent water supply to be supplied by Essex & Suffolk Water/NWL will be assessed as part of the separate regulatory processes associated with WRMP24, the Secretary of State has considered the relevant policy. Paragraph 4.10.3 of NPS EN-1 (EN-1), states that the decision-maker 'should work on the assumption that the relevant pollution control regime and other environmental regulatory regimes, including those on land drainage, water abstraction and biodiversity, will be properly applied and enforced by the relevant regulator. It should act to complement but not seek to duplicate them.' This text is carried forward in paragraph 4.11.5 of the draft revision of EN-1.

4.46 Paragraph 5.15.4 of EN-1 states 'The considerations set out in Section 4.10 on the interface between planning and pollution control therefore apply. These considerations will also apply in an analogous way to the abstraction licensing regime regulating activities that take water from the water environment, and to the control regimes relating to works to, and structures in, on, or under controlled water.' This text is carried forward to paragraph 5.16.6 of the draft revision of EN-1. Paragraph 5.15.6 states that the decision-maker 'should also consider the interactions of the proposed project with other plans such as Water Resources Management Plans'. This text is carried forward to paragraph 5.16.9 of the draft revision of EN-1.

4.47 The Secretary of State notes the EA's water resources planning guideline, updated on 4 April 20227, which states that water companies in England or Wales must prepare and maintain an WRMP that sets out how a water company intends to achieve a secure supply of water for its customers and a protected and enhanced environment. This guideline notes that the duty to prepare and maintain a WRMP is set out in sections 37A to 37D of the WIA and that a water company must prepare a plan at least every 5 years and review it annually. Part 3.1 of this guideline details the legal requirements relevant to the preparation and publication of a WRMP, including the need to take account of relevant legislation including the Conservation of Habitats and Species Regulations 2017. Part 3.3.1 notes that statutory consultees for the WRMP process includes the EA, and also notes that if possible options affect a designated site in England then the water company must contact NE. Part 4.1.1 notes that a water company should carry out a HRA as part of the WRMP process, including an appropriate assessment, as set out in the Conservation of Habitats and Species Regulations 2017 (as amended), if a preferred plan would be likely to have a significant effect on a European site (either alone or in combination with other plans or projects).

4.48 The Secretary of State notes the policy in Section 4.2 of EN-1. Paragraph 4.2.7 acknowledges that 'In some instances, it may not be possible at the time of the application for development consent for all aspects of the proposal to have been settled in precise detail.' This text has been carried forward to paragraph 4.2.5 of the draft revision of EN-1.

4.49 The Secretary of State considers that the Proposed Development and the WRMP24 process for the sourcing of water are separate projects. This is evident from their separate ownership and because they are subject to distinct and asynchronous determination processes. The Secretary of State also considers that these projects are stand-alone, given that NWL has a duty to undertake its WRMP24 regardless of whether or not the Proposed Development proceeds

4.50 The Secretary of State has considered the ExA's view [ER 7.5.7] that, even if the Proposed Development and the water supply are considered to be two separate projects, the cumulative effects associated with it should be assessed at this stage. As set out below, the Secretary of State has considered the cumulative assessment of the proposed pipeline from the North/Central WRZ and agrees with the Applicant's assessment that the pipeline is not likely to give rise to new or significant effects to those already identified in the ES. In addition, the Secretary of State agrees with the Applicant that the detail of the potential environmental impacts (including cumulative impacts) associated with the proposed permanent water supply to be provided by NWL will be sufficiently assessed and that the WRMP24 process is the appropriate means of undertaking that assessment. The Secretary of State agrees that further detailed assessment cannot be undertaken by the Applicant at this stage as the preferred option for long-term supply is not yet known given the current status of the separate WRMP24 process, which falls to be considered as a separate plan or project. The Secretary of State considers that it is because the long-term planning of water supply is subject to separate statutory provisions and processes, including those set out in paragraph 4.47 above, that the identification of the source of the

Proposed Development's long-term water supply cannot be known by the Applicant at this stage.

4.51 The Applicant's original and preferred water supply connection was a direct link from Barsham and the Applicant provided information about this, the cumulative effects of its preferred water supply solution of in Table 1.1 of the ES Addendum, Volume 3, Chapter 2, Appendix 2.2.D Water Supply Strategy submitted in January 2021. This refers to potable water transfer options and envisages that a supply of potable water via a direct link from Barsham would be provided by Essex and Suffolk Water. Table 1.1 notes that the provision of this link does not form part of the Application, however it provides a cumulative assessment of the Proposed Development with this link at Chapter 10 of the ES Addendum at paragraphs 10.4.229-10.4.250. The cumulative assessment states that "it is proposed that the detailed route alignment of the pipeline will follow existing roads and boundaries where possible" and that "it is anticipated that the earthworks for the cut and fill, and the pipelaying task for the preferred water supply proposal will progress quickly along the route and works would only impact upon a single receptor for a small number of days at most". In relation to Terrestrial ecology and ornithology it finds that "Given the footprint of the works and the proposed locations for working, ecological impacts would be minimal and avoidable or mitigable" and for all the other impacts assessed concludes that "no significant cumulative effects are anticipated in relation to the preferred water supply proposal and there would be no change to the residual cumulative effects as presented in Volume 10, Chapter 4 of the ES".

4.52 The Secretary of State has seen no subsequent evidence to suggest that anything has changed in that regard. The Secretary of State is satisfied that, based on current knowledge, there are no additional cumulative impacts if the Barsham pipeline were to be pursued. The Secretary of State has considered the information provided by the Applicant on cumulative effects and does not agree with the ExA's criticisms and considers there is sufficient information on which he can base his conclusion.

4.53 Section 3.2.3. of the revised Water Supply Strategy submitted at Deadline 7 in September 2021 stated that 'there is some potential spare capacity in the WRZ at NWL's Barsham Water Treatment Works near Beccles which is located in their Northern /Central WRZ, from which water is proposed to be transferred to Sizewell via a 28km pipeline. This transfer will also require other water network enhancements, which NWL are currently investigating. The proposed transfer main would connect into the local Blyth distribution network at Saxmundham Water Tower, and at other locations subject to detailed design. These local connections have the potential to provide significant legacy benefit by increasing capacity and resilience of the distribution network.'

4.54 The Statement of Common Ground agreed between NWL and the Applicant records that the proposal to transfer water from Barsham relies on abstraction from the River Waveney and its associated Waveney Augmentation Groundwater Scheme (WAGS) operated by the EA. It further records that on 26 August 2021 the EA informed NWL that a sustainability reduction may be applied to NWL's abstraction licence for the River Waveney and WAGS abstraction licenses which could reduce NWL's allowable annual quantities of

abstraction by up to 60% and that further modelling work is being carried out by NWL to investigate this.

4.55 The Secretary of State further notes the letter from Walker Morris on behalf of NWL on 23 February 2022 states that NWL will not be able to supply all forecast household and non-household demand, including the Proposed Development's long-term demand, from existing water resources, and that NWL will need to identify new water resources to meet the forecast demand. The Secretary of State notes that the letter states that in addition to demand management options, NWL is appraising options including (but not limited to) nitrate removal at Barsham WTWs to reduce raw water quality driven water treatment works outage. While noting that the ultimate source of supply has yet to be identified by NWL, the Secretary of State considers that the information provided demonstrates sufficiently, in principle, the viability of a mains connection pipeline to the Proposed Development if some or all of the supply were able to come from that location.

4.56 The Secretary of State is satisfied that if NWL, through the regulatory processes associated with the WRMP24, put forwards a solution to the supply of potable water supply which requires a change to the pipeline connection to the Proposed Development (once it has established where it will source the water for the Proposed Development from) any such solution will be subject to its own environmental assessments, including those under the HRA. The Secretary of State has not seen any information at this stage to suggest that a different pipeline connection (if it were to be required) would not be viable or its impacts unacceptable. However, this will be for NWL to assess once the source of the permanent water supply is known.

4.57 The Secretary of State notes that any such pipeline or connection will be applied for separately to the Proposed Development once there is certainty around its route and specification.

4.58 As set out above, the Secretary of State does not have detailed information as to the route or specification of the pipeline that would convey water to the Proposed Development given that it is subject to the outcome of the WRMP24 process which has not yet been completed. However, the Secretary of State considers that he has sufficient information for the purposes of taking a decision on the Proposed Development to conclude that there is the potential for a viable connection to be provided in principle. The Secretary of State considers that if the pipeline connects to a supply at Barsham it is not likely to give rise to significant environmental effects additional to those already identified in the Environmental Statement, but this will also fall to be re-examined and be subject to assessment once any such pipeline connection is finalised. If a different solution is required, then any such different solution will need to be the subject of its own assessments in due course.

4.59 The Secretary of State notes that in light of the matters identified above it is not possible for the Applicant to provide more specific details regarding the route or specification of the pipeline, or other connection, that will provide the Proposed Development with a connection to the water main or water supply at this stage, and notes that such a pipeline or alternative connection does not form

part of the Application. This is due to the fact that the specific details of the route remain unknown until NWL identifies the source of the water that the pipeline will connect the Proposed Development to. The Secretary of State considers that such a pipeline or alternative connection cannot be subject to more detailed assessment as part of this Application given it is subject to the WRMP24. The Secretary of State notes that whilst the Water Supply Strategy submitted in January 2021 identified that the pipeline between Barsham and the Proposed Development did not form part of the Application, a cumulative assessment of the Proposed Development with that pipeline was undertaken, and that the Application was accepted on that basis. The Secretary of State agrees that in light of the present state of knowledge, it is not possible for the Applicant to conduct any meaningful assessment of any different solution to emerge from the WRMP24 process but that any such different solution will necessarily be subject to its own assessment before it can proceed.

4.60 The policy set out in NPS EN-1 is clear that a decision-maker should work on the assumption that relevant environmental regulatory regimes, including the abstraction licencing regime regulating activities that take water from the water environment, will be properly applied and enforced by the relevant regulator, and that a decision-maker should not seek to duplicate these regimes. The policy is also clear that the decision-maker should have regard to the interaction between the proposed project and other plans, and references Water Resource Management Plans as a specific example of such plans. The Secretary of State notes the acknowledgement in Section 4.2 of EN-1 that it is not always possible for all aspects of a proposal to be settled in precise detail. The fact that there is a lack of detailed information available regarding the source of a permanent water supply via NWL means that it is not possible for the Applicant to have assessed the effect, including the cumulative effects of all of the potential means of conveying water to the Proposed Development. The WRMP process is conducted by the water company and is not something that the Applicant can dictate. If (and only if) the WRMP process fails to provide a solution, the Applicant will have to consider its own permanent desalination plant.

4.61 The Secretary of State notes the concerns raised by IPs regarding the prospect of a permanent desalination plant. The Secretary of State agrees with the Applicant that further detailed assessment of the impacts associated with a permanent desalination plant would be required if the Applicant were ultimately to pursue this option as part of its water supply strategy which is not the current intention. The Secretary of State has not requested further detailed assessment from the Applicant of this option given that it does not form part of the Proposed Development and the Applicant's position is that a bespoke permanent desalination plant for the Proposed Development is unlikely to be required. The Secretary of State notes the Applicant's position that a permanent desalination plant is not likely to generate any materially new or materially different significant environmental effects on the marine environment (see paragraph 2.2.8 of the Applicant's response to the Secretary of State's letter of 18 March 2022) and on the terrestrial environment (see paragraph 2.2.10 of the Applicant's response to the Secretary of State's letter of 18 March 2022). The Secretary of State has also considered the concerns raised by IPs regarding the fact that the Applicant had previously discounted desalination from its water

supply options. The Secretary of State notes that the revision 1.0 of the Applicant's Water Supply Strategy produced in May 2020 noted that benefits of desalination include potentially short lead times with equipment available for hire, and that it could be useful for temporary top-ups or in times of drought. The limitations of desalination were listed as 'desalinated water being aggressive in pipe network and may require remineralisation'.

4.62 The Secretary of State acknowledges (above) that the Applicant's conclusion in January 2021, in Appendix 2.2.D Water Supply Strategy of the ES Addendum Volume 3 Chapter 2, was to discount the installation of a modular desalination plant on the MDS and the abstraction of seawater for treatment and notes that the Applicant also stated in the same document that Essex and Suffolk Water had 'identified means to provide a viable supply of potable water to Sizewell C' with this option referred to as 'transfer of surplus potable water via a new pipeline from Barsham'. This reflected the Applicant's position that a new mains pipeline is preferable to a permanent desalination plant.

4.64 The Secretary of State notes that revision 2.0 of the Water Supply Strategy published in September 2021 sets out the important role that a temporary desalination plant would play in the overall strategy. The Secretary of State acknowledges that the Applicant's position on desalination has therefore changed between January 2021 and September 2021 as a result of new information becoming available to the Applicant regarding the preferred mains connection via NWL. The Secretary of State is content that it is reasonable for the Applicant to rely on revision 2.0 of the Water Supply Strategy submitted during the Planning Inspectorate's examination of the Proposed Development in light of the new information that became available via NWL in terms of the important role that a temporary desalination plant would play in the overall strategy. The Secretary of State considers that if, contrary to expectation, the Applicant were to seek to provide water from a permanent desalination plant, that would require its own consent and would be subject to further detailed assessment at that stage before it could proceed. Accordingly, for essentially the same reasons as identified above in respect of the other potential solutions to the supply water strategy, the Secretary of State does not consider it necessary for the effects of any such solution to be assessed in more detail as a permanent desalination plant does not form part of the Proposed Development and the Applicant is not relying on it as an integral part of the Proposed Development.

4.64 The Secretary of State notes and agrees with the position of the ONR that in order to fulfil the Licence Conditions of any nuclear site licence necessary to operate the power station, the Applicant will have to put in place a reliable source of water before any nuclear safety related activities can take place that are dependent on such a supply. Accordingly, the Secretary of State is satisfied that the issue of a sustainable water supply solution will be subject to control through the nuclear site licence application and a reliable source of water will need to be demonstrated before any nuclear safety related activities can take place. The Secretary of State notes that NWL has included the demand from the Proposed Development in its WRMP24 Demand Forecast and NWL remains committed to providing the Proposed Development with a long term water supply and is therefore satisfied that there is a requisite degree of confidence

that a long term solution is deliverable, that any such long term solution will be subject to its own environmental assessment, including any required under the Habitats Regulations, which will consider cumulative and incombination effects before it can proceed, and that the ability to deliver that solution will need to be demonstrated to fulfil the Licence Conditions of any nuclear site licence to enable the Proposed Development to generate power.

4.65 In relation to the Habitats Regulations, the Secretary of State does not agree with Natural England that the source of any permanent water supply is, in itself, integral to the application. There will need to be a permanent water supply solution and the Secretary of State is satisfied that such a solution can be found before the first reactor is commissioned. However, the Secretary of State does not consider that the source of that supply is an integral part of this application. There is no current certainty as to the final source of the permanent water supply, which does not need to be in place until the early 2030s. The Applicant has carried out a cumulative assessment of the potential pipeline route from Barsham/the North/Central WRZ which identifies that this will result in no new or different significant cumulative effects. However, it is not currently known whether this or some other means of connecting the development to the water supply network will be required and this is something that will only become known through the WINEP process. The Secretary of State agrees with the position of the Applicant that an assessment of the Habitats Regulations implications of the proposed permanent water supply solution will be undertaken by NWL. The Secretary of State does not agree with NE that any such assessment is likely to miss or underplay any effects of any kind, including any cumulative or in-combination effects.

4.66 In the unlikely event that NWL can find no solution, then the Applicant has confirmed that it would seek to take forward its own solution of the construction of a permanent desalination plant. As already noted, this in itself would require a further application, either to amend the DCO or for another form of planning consent and such an application would similarly trigger the requirement for the necessary environmental assessments including any required under the Habitats Regulations. Such assessment would consider the proposed permanent water supply solution in combination with the Proposed Development and address any cumulative effects

Overall Conclusion on Water Supply

4.67 The Secretary of State is satisfied that the Applicant has established an acceptable water supply strategy for the construction period. The Secretary of State is also satisfied that a long-term water supply is viable and that any proposed water supply solution to be supplied by NWL will be properly assessed under the WRMP24 process and/or other relevant regulatory regimes and considers that no further information is required regarding the proposed water supply solution for a decision to be taken on the Application.

4.68 The Secretary of State therefore disagrees with the ExA's conclusions on this matter and considers that the uncertainty over the permanent water supply strategy is not a barrier to granting consent to the Proposed Development

4.69 The Secretary of State considers that the matter of the water supply does not weigh for or against the Order being made, and attributes this matter neutral weight in the overall planning balance.

Appendix D Stantec EIA Review on behalf of SKDC and RCC

Mallard Pass Solar Farm
Environmental Statement Review

May 2023

Mallard Pass Solar Farm
Environmental Statement Review

Prepared on behalf of Rutland County Council and South Kesteven District Council

Job Number:	33848/A5/EIA Scoping Review	
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1 INTRODUCTION

Report Purpose

1.1 This document sets out the findings of an independent review of the Mallard Pass Solar Farm Environmental Statement[i] undertaken on behalf of Rutland County Council and South Kesteven District Council in their role as statutory consultees to a proposed application for a Development Consent Order under the Planning Act 2008[ii]. The ES was prepared by the Applicant Mallard Pass Solar Farm Ltd, a subsidiary of Windel Energy Ltd and development partner Canadian Solar, in accordance with the *Infrastructure Planning (Environmental Impact Assessment) Regulations 2017*[iii].

Proposed Development and Site

1.2 The proposals comprise the installation of solar photovoltaic electricity generating panels and associated infrastructure which would allow for the generation of 350 megawatts (MW) on an 852 hectare site at Mallard Pass, Essendine located in the counties of Rutland and Lincolnshire. The key components of the development comprise:

- PV Arrays;
- Mounting Structures;
- Inverters;
- Transformers;
- Switchgears;
- Onsite Substation and Ancillary Buildings;
- Low Voltage Distribution Cabling;
- Grid Connection Cables;
- Fencing, security and ancillary infrastructure;
- Access Tracks;
- Temporary Construction Compounds;
- Mitigation and Enhancement Areas; and
- Green infrastructure (GI).

ES Report Review Methodology

1.3 This review of the Mallard Pass ES is based on the requirements of the Infrastructure EIA Regulations, as set out above. Barton Willmore, now Stantec, as IEMA Quality Mark practitioners, have extensive experience in the production ESs for DCO EIA developments.

Limitations

1.4 There are a number of limitations of this review as follows:

- The review has been desk based and has not involved a site visit so statements about the baseline and existing site description and context are taken as correct;
- It is not the purpose of the review to provide an in-depth technical check of the individual specialist discipline areas. This means that the review does not:
  - Check the actual survey work undertaken was fully executed according to the cited methods; or
  - Review the consultation undertaken.
- The review has not been undertaken by a legal professional.

Structure of the Review Report

1.5 The structure of this review report is as follows:

- Chapter 2 contains tables comprising the ES Review; and
- Chapter 3 provides the conclusions.

2 ES REVIEW TABLES

Table 2.1: ES Regulatory Compliance

EIA Regulation Requirements	COMMENTS	Action Required

1
A description of the development, including in particular—
 	
a) a description of the location of the development;
b) a description of the physical characteristics of the whole development, including, where relevant, requisite demolition works, and the land-use requirements during the construction and operational phases;
c) a description of the main characteristics of the operational phase of the development (in particular any production process), for instance, energy demand and energy used, nature and quantity of the materials and natural resources (including water, land, soil and biodiversity) used;
d) an estimate, by type and quantity, of expected residues and emissions (such as water, air, soil and subsoil pollution, noise, vibration, light, heat, radiation and quantities and types of waste produced during the construction and operation phases.
	• Chapters 3 and 5, and relevant sections of the technical assessment chapters provide a comprehensive description of the proposed development including:
	  • physical characteristics;
	  • land use requirements; and
	  • characteristics of the operational phase.
	• The number of solar panels required has been provided and dimensions of the components of the development have been provided.
	• Types of waste have been identified in Chapter 15.
		• None

2 A description of the reasonable alternatives (for example in terms of development design, technology, location, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects.	• Chapter 4 provides details of the Alternatives considered.	• None
3. A description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge.	• The baseline conditions are comprehensively described in Chapter 3 Order Limits and each of the technical assessments (Chapters 6-15).	• None
4 A description of the factors specified in regulation 5(2) likely to be significantly affected by the development: population, human health, biodiversity (for example fauna and flora), land (for example land take), soil (for example organic matter, erosion, compaction, sealing), water (for example hydromorphological changes, quantity and quality), air, climate (for	• For the topics included in the ES, the environmental factors likely to be significantly affected have been identified and clearly described.	• None

EIA Regulation Requirements	COMMENTS	Action Required
example greenhouse gas emissions, impacts relevant to adaptation), material assets, cultural heritage, including architectural and archaeological aspects, and landscape.		
5 A description of the likely significant effects of the development on the environment resulting from, inter alia— a) the construction and existence of the development, including, where relevant, demolition works; b) the use of natural resources, in particular land, soil, water and biodiversity, considering as far as possible the sustainable availability of these resources; c) the emission of pollutants, noise, vibration, light, heat and radiation, the creation of nuisances, and the disposal and recovery of waste; d) the risks to human health, cultural heritage or the environment (for example due to accidents or disasters); e) the cumulation of effects with other existing and/or approved projects, taking into account any existing environmental problems relating to areas of particular environmental importance likely to be affected or the use of natural resources; f) the impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change; g) the technologies and the substances used. h) The description of the likely significant effects on the factors specified in regulation 5(2) should cover the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the development. This description should take into account the environmental protection objectives established at Union or Member State level which are relevant to the project, including in particular those established under Council Directive 92/43/EEC(**1**) and Directive 2009/147/EC(**2**).	• The ES was subject to a Scoping exercise, the Applicant has undertaken comprehensive consultation, and a Preliminary Environmental Information Report was prepared which further refined the scope and content of the ES. • The assessment has identified cumulative and intra-project effects; • Types of effect have also been identified including short/long term, permanent/temporary etc; • Cumulative effects have been identified in detail.	• None
6. A description of the forecasting methods or evidence, used to identify and assess the significant effects on the environment, including details of difficulties (for example technical deficiencies or lack of knowledge) encountered compiling the required information and the main uncertainties involved.	• The assessment methodologies adopted for each of the technical assessments have been clearly set out along with assumptions and limitations	• None
7. A description of the measures envisaged to avoid, prevent, reduce or, if possible, offset any identified significant adverse effects on the environment and, where appropriate, of any	• Detailed mitigation measures have been included in the ES and Appendix 17.1, however, Appendix 17.1 provides a key	• None

EIA Regulation Requirements	COMMENTS	Action Required
proposed monitoring arrangements (for example the preparation of a post-project analysis). That description should explain the extent, to which significant adverse effects on the environment are avoided, prevented, reduced or offset, and should cover both the construction and operational phases.	summary and it is felt this would have been better placed in the main text. This is not a serious flaw. • The mitigation measures are identified as either embedded or additional mitigation and both types are well explained.	
8. A description of the expected significant adverse effects of the development on the environment deriving from the vulnerability of the development to risks of major accidents and/or disasters which are relevant to the project concerned. Relevant information available and obtained through risk assessments pursuant to EU legislation such as Directive 2012/18/EU of the European Parliament and of the Council(**3**) or Council Directive 2009/71/Euratom(**4**) or UK environmental assessments may be used for this purpose provided that the requirements of this Directive are met. Where appropriate, this description should include measures envisaged to prevent or mitigate the significant adverse effects of such events on the environment and details of the preparedness for and proposed response to such emergencies.	• Accidents and disasters are considered in: • Chapter 15, • Chapter 11 and Appendix 11.5 - Flood Risk; and • Chapter 13 – Climate Change. • There was no requirement for other European assessments as part of the proposed development.	• None
9. A non-technical summary of the information provided under paragraphs 1 to 8.	• A separate standalone NTS is provided	• None
10. A reference list detailing the sources used for the descriptions and assessments included in the environmental statemen	• Each technical assessment provides a reference list as do the majority of the technical appendices	• None

Table 2.2: Advice Note 7[iv] Compliance

Advice Note Seven: Environmental Impact Assessment: Process, Preliminary Environmental Information and Environmental Statements	COMMENTS	Action Required
Paragraph 9.3 states "The Planning Inspectorate considers that a good ES is one that:		• None
• provides a clear description of the Proposed Development through all phases of the development consistent with the DCO ie in terms of construction, operation and decommissioning phases;	• It is considered that the Mallard Pass ES provides a clear description of the proposed development through all phases;	
• clearly explains the processes followed to develop the ES including the established scope for the assessment;	• The ES clearly explains the processes used to develop the ES and the established scope;	
• explains the reasonable alternatives considered and the reasons for the chosen option taking into account the effects of the Proposed Development on the environment;	• The ES includes reasonable alternatives and the reasons for the option chosen;	

Advice Note Seven: Environmental Impact Assessment: Process, Preliminary Environmental Information and Environmental Statements	COMMENTS	Action Required
• details the forecasting methods for the assessment and the limitations (as relevant);	• Forecasting methods for the assessment and limitations are clearly set out;	
• assesses in an open and robust way the assessment of likely significant effects explaining where results are uncertain;	• The ES assesses in a robust open way the likely significant effects of the proposed development;	
• provides sufficient details of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects, the likely efficacy of such measures and how they are secured;	• Sufficient details of the proposed mitigation measures and mechanisms to deliver monitoring are provided. It is considered that Appendix 17.1 should have been included in the main ES text as opposed to being provided as an appendix given the importance of the information however this is not a fatal error. The expected efficacy of the mitigation measures proposed is not discussed in the ES however the mitigation proposed is not novel or contain unfamiliar processes therefore this is also not considered a serious error.	
• details the need for any ongoing monitoring or remediation; and	• Monitoring is identified in the ES along with the mechanism to secure monitoring.	
• demonstrates that the information is sufficient to enable a reasoned conclusion to be reached.	• The information provided in the ES is sufficient to reach a reasoned conclusion.	

Table 2.3: Technical Content of Topics within the ES

Chapter Number	Chapter Title	Review Comments
N/A	Glossary	• Listed of Appendices and Figures included after Glossary which is helpful but is not mentioned in Chapter name
1	Introduction	• Whilst the glossary is helpful and the importance of brevity in the ES main text is recognised, it is considered that explanation of key terms such as Order Limits and Work Plans would be been better included in Chapter 1 to ensure clear understanding of the proposed development. • Other than that, Chapter clear and logical
2	Overview of EIA process	• Standard information provided. • Chapter clear. • Para 2.5.21 states "*There are no monitoring requirements identified within this ES*". Whilst monitoring may not be required it is noted that several chapters (e.g. Ch 14 Socio-economics) include references to monitoring. This is a minor issue that does not require corrective action but suggest monitoring proposed is undertaken through a DCO requirement.
3	Order limits Description	• The term Order limits is considered awkward and Site would have been clearer – with the site defined as the Order limits. • No other comments.
4	Alternatives and Design Development	• Chapter clear and comprehsive.

Chapter Number	Chapter Title	Review Comments
5	Project Description	• Minor comment but 'Authorised Development' not defined in the chapter or the Glossary
6	Landscape and Visual	• No comments.
7	Ecology and Biodiversity	• No comments.
8	Cultural heritage	• No comments.
9	Highways and Access	• Minor discrepancy in referring to three and four permissive paths.
10	Chapter 10 – Noise and Vibration	No comments.
11	Chapter 11 – Water Resources and Ground Conditions	• No comments.
12	Chapter 12 – Land Use and Soils	• No comments.
13	Chapter 13 – Climate Change and Resilience	• Chapter scope could have been tighter given PINS consultation comments identified that only resilience and GHG calculations need be addressed, however this is not a deficiency as it has been over, rather than under scoped.
14	Chapter 14 – Socio-Economics	• No comments.
15	Chapter 15 – Other Environmental Topics (comprising Air Quality, Arboriculture, Glint and Glare, Major Accidents and/or Disasters, Utilities/EMF, Waste)	• Unclear why Glint and Glare report singles out property 166 for additional mitigation when it appears the embedded mitigation also focuses on mitigation for individual properties. • Unclear why the Arboricultural Impact Assessment is included when PINS agreed in consultation the topic could be scoped out. • Minor inconsistency in referencing to Cumulative Long List. • SKDC Tree Preservation Order information not provided to the Applicant • These minor inconsistencies do not require corrective action.
16	Chapter 16 – Interaction of Effects and Cumulative Effects	• No comments
17	Chapter 17 – Summary of Effects	• Minor inconsistency in the Agricultural Land text between Chapters 17 and Chapter 12. Chapter 17 includes Additional Mitigation Measures in the form of development design however this is not set out in the Land and Soils chapter. It is a minor point that does not require corrective action.
General comment		• Several appendices have redacted text- some redactions are errors and blocking text that is not sensitive e.g. Appendix 11.6 and Appendix 8.5

3 CONCLUSIONS

3.1 This document provides an independent review of the Mallard Pass Environmental Statement submitted to the Planning Inspectorate in advance of an application for a Development Consent Order to permit the construction of a 350mw solar farm on an 852 hectare site at Mallard Pass, Essendine located in the counties of Rutland and Lincolnshire. The review has identified that the ES:

- is in compliance with the Infrastructure EIA Regulations' requirements;
- is in compliance with the requirements of Advice Note 7;
- comprehensively identifies and assesses the likely significant effects of the proposed development;
- provides sufficient information to allow the Planning Inspector to make an informed decision on the Development Consent Order; and
- As with the EIA Scoping Report, and PEIR, the ES includes some superfluous detail and minor errors but given the scale of the ES, these are not deficiencies that require corrective action.

RFERERNCES

[i] ES: https://www.mallardpasssolar.co.uk/documents
[ii] Planning Act 2008 (legislation.gov.uk)
[iii] https://www.legislation.gov.uk/uksi/2017/572/made#f00020
[iv] https://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/advice-notes/advice-note-seven-environmental-impact-assessment-process-preliminary-environmental-information-and-environmental-statements/#8

Appendix E Swept Patch Analysis Drawings

C:\USERS\GFLETCHER\VTP\VTP - CAD\LDA_4990\2002_MALLARD PASS SOLAR FARM\ACAD\1.0.CURRENT\1.0.1.SHEETS\AROWS\4990-2001-T-067-068-P0 - SWEPT PATH ANALYSIS OF 16.5M ARTICULATED VEHICLE & CAR PASSING.DWG

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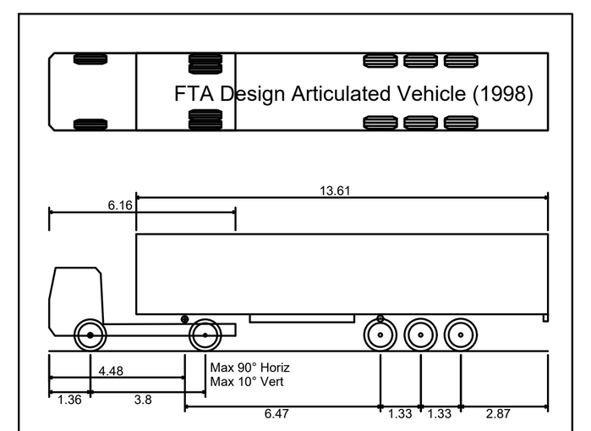
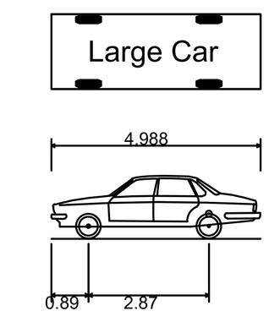
LEGEND



FTA Design Articulated Vehicle (1998)	
Overall Length	16.480m
Overall Width	2.550m
Overall Body Height	3.870m
Min Body Ground Clearance	0.515m
Max Track Width	2.470m
Lock to lock time	3.00s
Kerb to Kerb Turning Radius	6.550m



Large Car	
Overall Length	4.988m
Overall Width	1.793m
Overall Body Height	1.502m
Min Body Ground Clearance	0.287m
Track Width	1.700m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	6.200m

Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of 16.5m articulated vehicle and large car passing

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER
EN010127

ISSUED BY	Oxford	T: 01865 887 050	
DATE	28 June 2023	DRAWN	GSF
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STATUS	Final	APPROVED	RP

DWG. NO 4990-2001-T-067 **REV : P0**

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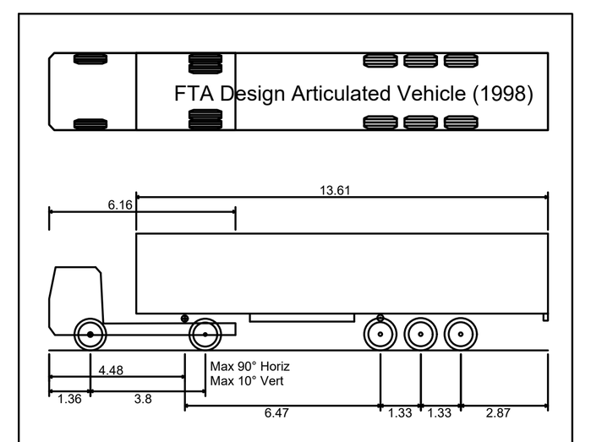

FTA Design Articulated Vehicle (1998)	
Overall Length	16.480m
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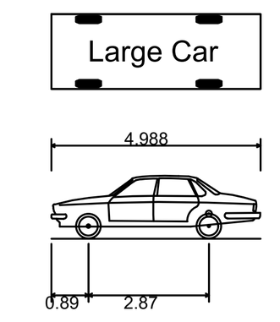
Overall Body Height	3.870m
Min Body Ground Clearance	0.515m
Max Track Width	2.470m
Lock to lock time	3.00s
Kerb to Kerb Turning Radius	6.550m



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Lock to lock time	4.00s
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Key Plan

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PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of 16.5m articulated vehicle and large car passing

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER
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DWG. NO 4990-2001-T-068 **REV : P0**

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Sources Ordnance Survey

0 10m

North

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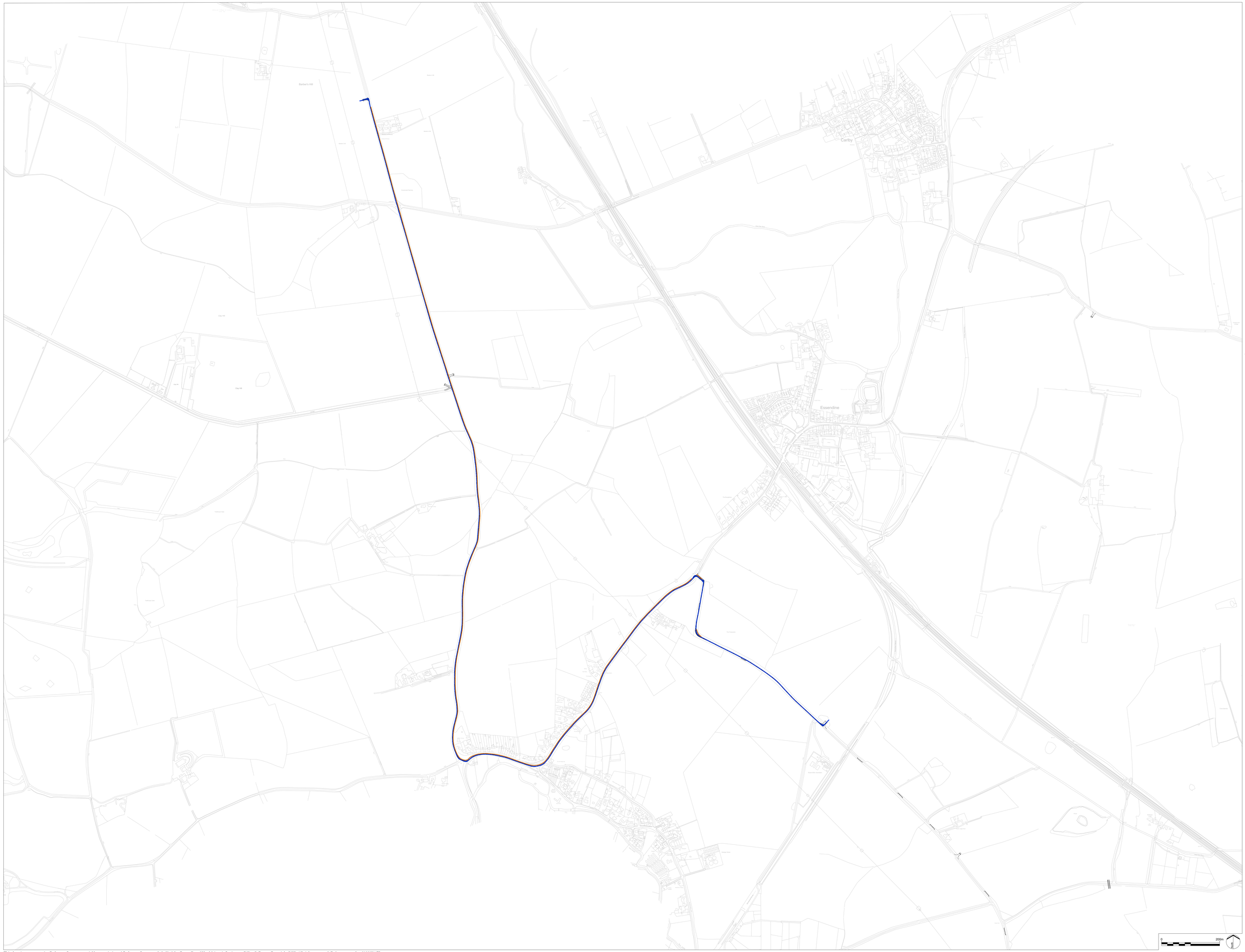

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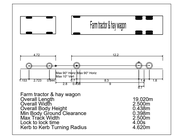

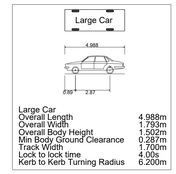

Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of tractor + trailer & car passing Primary to Secondary - Route 1

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER
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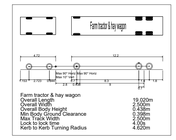
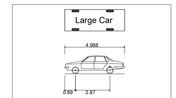


Farm tractor & hay wagon	
Overall Length	19.020m
Overall Width	2.550m
Overall Body Height	3.430m
Min Body Ground Clearance	0.395m
Track Width	2.700m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	4.620m



Large Car	
Overall Length	4.988m
Overall Width	1.793m
Overall Body Height	1.502m
Min Body Ground Clearance	0.287m
Track Width	1.700m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	6.200m

Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of tractor + trailer & car passing
Primary to Secondary - Route 1

Infrastructure Planning (Examination Procedure)
Rules 2010

PINS REFERENCE NUMBER
EN010127

ISSUED BY	Oxford	T: 01865 887 050	
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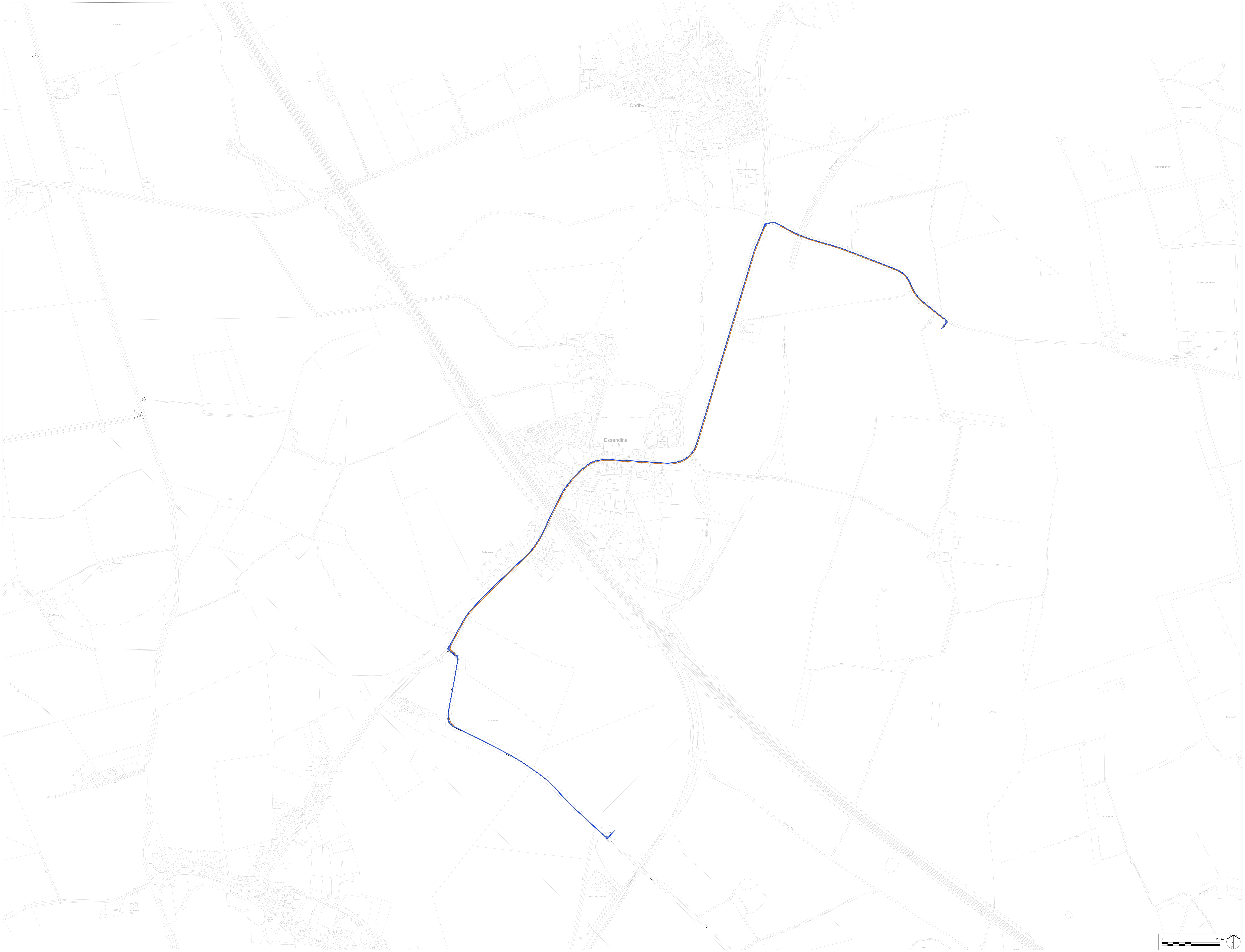

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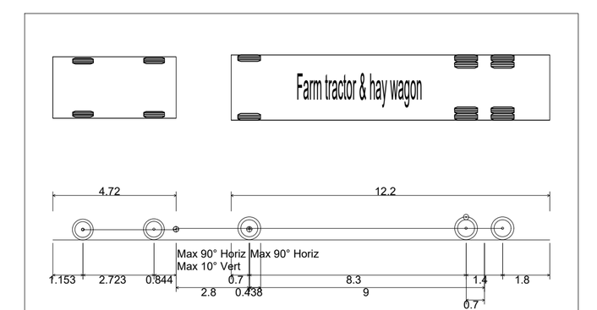
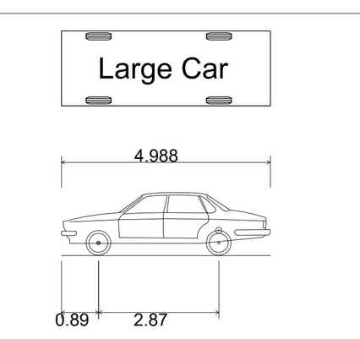


Farm tractor & hay wagon	
Overall Length	19.020m
Overall Width	2.500m
Overall Body Height	0.438m
Min Body Ground Clearance	0.398m
Max Track Width	2.500m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	4.620m



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Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of tractor + trailer & car passing
Primary to Secondary - Route 2

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER
EN010127

ISSUED BY	Oxford	T: 01865 887 050	
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DWG. NO 4990-2001-T-071 REV : P0

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Sources Ordnance Survey

0 200m North

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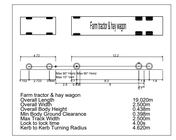

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Overall Body Height	3.430m
Min Body Ground Clearance	0.395m
Track Width	2.000m
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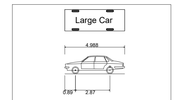

Large Car

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Track Width	1.700m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	6.200m

Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE

MALLARD PASS SOLAR FARM

DRAWING TITLE

Swept path analysis of tractor + trailer & car passing Primary to Secondary - Route 2

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER

EN010127

ISSUED BY	Oxford	T: 01865 887 050	
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Sources: Ordnance Survey

0 200m

Appendix F Article on Solar Farms and Impacts to Biodiversity

Large-Scale Solar

National survey finds that well managed solar farms can address loss of biodiversity

Published: 24 May 2023, 09:24

By:

John Lubbock

Section editor, Solar Media

Image: Solar Energy UK

A national survey of wildlife on solar farms has found that they can be havens for wildlife when specifically managed for conservation.

Solar Energy UK's *Solar Habitat: Ecological trends on solar farms in the UK*, has found that several declining bird species such as the Linnet, Yellowhammer and Skylark are present at half of the solar farms who took part in the survey.

The survey uses a standardised approach to ecological monitoring set out by Solar Energy UK last year to better make comparisons across solar sites. To do this, they partenered with Clarkson & Woods, Wychwood Biodiversity and Lancaster University, "providing a uniform approach to how the solar industry collects ecological monitoring data on solar sites. This allows for the amalgamation of data, forming a robust, credible evidence base showing the ecological trends on solar farms."

Hollie Blaydes, the PhD student who led the research said: "It is very clear that solar farms can be wildlife havens. About half of the solar farms surveyed are managed with conservation specifically in mind, such as limiting grazing to only certain times of the year and reducing herbicide use. It's on these where wildlife can really thrive and benefit from the habitats [illegible]d."

Blaydes added that the survey findings and a requirement for new developments to include at least 10% Biodiversity Net Gain (BNG) could encourage the renewable industry to improve biodiversity even further.

The report notes that “the low intensity of management on solar farms, as well as the range of habitats present, can support a variety of invertebrate species.” These species support other forms of biodiversity as food or pollinators.

Biodiversity at solar farms was “strongly associated with management being more focused on wildlife. Almost all sites (94%) had some conservation measures, graded 2-3 on a 1-5 scale, where one is optimal.”

“This report confirms what we have known anecdotally for many years: well-designed and well-managed solar farms can help address the climate emergency and loss of biodiversity in the UK, said Rachel Hayes, consents and ESG policy manager at Solar Energy UK.

“Wildlife can benefit hugely from developing solar farms, providing a variety of habitats and raising the numbers of some of our most threatened species while pushing us forward towards net zero. I hope that the report’s findings will encourage more asset owners to adopt the standardised approach to monitoring ecology on solar farms and make the results even more robust,” she added.

Under the provisions of the Environment Act 2021, all development schemes in England will need to deliver a mandatory 10% biodiversity net gain to be maintained for a period of at least 30 years. The provision comes into force in November 2023, but many solar developments are already making provisions for increasing biodiversity on site.

Solar Power Portal reported recently on a solar farm project by Banks Renewables that recently recieved council consent in Rotherham: "Banks Renewables will produce a detailed ecology and biodiversity strategy, with the aim that the site delivers a net benefit in biodiversity."

More articles in: Solar Pv | Renewables | Solar | Uk | Biodiversity | Solar Energy Uk | Habitat | Climate Emergency | Climate Crisis | Biodiversity Net Gain | Lancaster University

Related Event

UK Solar Summit

27 JUN - 28 JUN, 2023 • LONDON Join us in London for 2 days as we look at the UK's new landscape for utility & rooftop solar. Understand the new opportunities within this GW-plus annual market!

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2 Chris Skidmore MP and solar taskforce leaders share the latest on the group's progress

3 Energy minister Graham Stuart says government is working hard to meet 70GW solar target

4 Solar could increase value of homes by up to £10,000, study finds

5 UK government grants development consent order for EDF Renewables' solar farm in Essex

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is Skidmore MP and solar taskforce leaders share the latest on the group's

progress

Energy minister Graham Stuart says government is working hard to meet 70GW solar target

Solar could increase value of homes by up to £10,000, study finds

Appendix G GHG Calculations Table

Operational carbon saving variables	Value	Unit	Note
Capacity of Proposed Development	350	MW	Indicative installed panel capacity
Annual Load Factor Year 0	11.40%	%	Solar Load Factor
Hours / Year	8,760	Hours	
Year 1 Degradation	2%	% / Year	Conservative estimate for Year 1
Year n Degradation	0.45%	% / Year	Conservative estimate for subsequent years
UK Grid Carbon Intensity	182	Kg/MWh	Digest of UK Energy Statistics (DUKES) indicate the average emission of CO2 in 2020 across the mix of sources of electricity that currently contribute power to the grid Refer Environmental Statement Volume 1 Chapter 13: Climate Change Paragraph 13.4.17

Construction Carbon cost variables	Value	Unit	Note
Annual output expectation at construction	349,524	MWh	Calculation from above
Indicative Lifetime of the Proposed Development	40	Years	Indicative assumption
IPCC estimated emissions of CO2 utility scale solar photovoltaic cells kgCO2eq/MWh (associated with construction, operation (negligible) and decommissioning)	48	Kg CO2eq/MWh	IPCC estimated emissions of CO2 utility scale solar photovoltaic cells
Total carbon cost of the Proposed Development including: construction, operation (negligible) and decommissioning	672,000	Te CO2	Refer Environmental Statement Volume 1 Chapter 13: Climate Change Paragraph 13.4.14
Annual amortised carbon cost	16,800	Te CO2 / Year	

Year	Annual Production accounting for degradation (MWh/Yr)	UK Grid Carbon Intensity (Kg/MWh)	Carbon saving of the Proposed Development (Kg CO2 / Year)	Amortised lifetime carbon cost (Kg CO2 / Year)	Each year of operation brings about a carbon saving vs. the amortised lifetime carbon cost (Kg CO2 / Year saved)	Annual carbon savings vs. Amortised lifetime carbon cost (Te CO2 / Year saved)	Cumulative carbon saving vs. Grid carbon intensity (Te CO2)	Cumulative carbon savings vs. Lifetime carbon cost (Te CO2)
1	349,524	182	63,613,368	16,800,000	46,813,368	46,813	63,613	-608,387
2	342,534	182	62,341,101	16,800,000	45,541,101	45,541	125,954	-546,046
3	340,992	182	62,060,566	16,800,000	45,260,566	45,261	188,015	-483,985
4	339,458	182	61,781,293	16,800,000	44,981,293	44,981	249,796	-422,204
5	337,930	182	61,503,277	16,800,000	44,703,277	44,703	311,300	-360,700
6	336,409	182	61,226,513	16,800,000	44,426,513	44,427	372,526	-299,474
7	334,896	182	60,950,993	16,800,000	44,150,993	44,151	433,477	-238,523
8	333,389	182	60,676,714	16,800,000	43,876,714	43,877	494,154	-177,846
9	331,888	182	60,403,669	16,800,000	43,603,669	43,604	554,557	-117,443
10	330,395	182	60,131,852	16,800,000	43,331,852	43,332	614,689	-57,311
11	328,908	182	59,861,259	16,800,000	43,061,259	43,061	674,551	2,551
12	327,428	182	59,591,883	16,800,000	42,791,883	42,792	734,142	62,142
13	325,955	182	59,323,720	16,800,000	42,523,720	42,524	793,466	121,466
14	324,488	182	59,056,763	16,800,000	42,256,763	42,257	852,523	180,523
15	323,028	182	58,791,007	16,800,000	41,991,007	41,991	911,314	239,314
16	321,574	182	58,526,448	16,800,000	41,726,448	41,726	969,840	297,840
17	320,127	182	58,263,079	16,800,000	41,463,079	41,463	1,028,104	356,104
18	318,686	182	58,000,895	16,800,000	41,200,895	41,201	1,086,104	414,104
19	317,252	182	57,739,891	16,800,000	40,939,891	40,940	1,143,844	471,844
20	315,825	182	57,480,061	16,800,000	40,680,061	40,680	1,201,324	529,324
21	314,403	182	57,221,401	16,800,000	40,421,401	40,421	1,258,546	586,546
22	312,988	182	56,963,905	16,800,000	40,163,905	40,164	1,315,510	643,510
23	311,580	182	56,707,567	16,800,000	39,907,567	39,908	1,372,217	700,217
24	310,178	182	56,452,383	16,800,000	39,652,383	39,652	1,428,670	756,670
25	308,782	182	56,198,348	16,800,000	39,398,348	39,398	1,484,868	812,868
26	307,393	182	55,945,455	16,800,000	39,145,455	39,145	1,540,813	868,813
27	306,009	182	55,693,700	16,800,000	38,893,700	38,894	1,596,507	924,507
28	304,632	182	55,443,079	16,800,000	38,643,079	38,643	1,651,950	979,950
29	303,261	182	55,193,585	16,800,000	38,393,585	38,394	1,707,144	1,035,144
30	301,897	182	54,945,214	16,800,000	38,145,214	38,145	1,762,089	1,090,089
31	300,538	182	54,697,960	16,800,000	37,897,960	37,898	1,816,787	1,144,787
32	299,186	182	54,451,820	16,800,000	37,651,820	37,652	1,871,239	1,199,239
33	297,839	182	54,206,786	16,800,000	37,406,786	37,407	1,925,446	1,253,446
34	296,499	182	53,962,856	16,800,000	37,162,856	37,163	1,979,408	1,307,408
35	295,165	182	53,720,023	16,800,000	36,920,023	36,920	2,033,128	1,361,128
36	293,837	182	53,478,283	16,800,000	36,678,283	36,678	2,086,607	1,414,607
37	292,514	182	53,237,631	16,800,000	36,437,631	36,438	2,139,844	1,467,844
38	291,198	182	52,998,061	16,800,000	36,198,061	36,198	2,192,842	1,520,842
39	289,888	182	52,759,570	16,800,000	35,959,570	35,960	2,245,602	1,573,602
40	288,583	182	52,522,152	16,800,000	35,722,152	35,722	2,298,124	1,626,124

Observations
The Proposed Development delivers a gross carbon benefit vs. current grid carbon intensity for every year of operation
The Proposed Development delivers a net carbon benefit vs. amortised lifetime carbon cost for every year of operation
The Proposed Development delivers a net carbon benefit vs. total lifetime carbon cost from Year 10/11 onwards
The Proposed Development delivers a total net carbon benefit of 1.6 million tonnes of CO2 over a 40 year lifetime

The Applicant has used conservative assumptions to calculate these figures

Appendix H EPD PV Acciona_El Romano Solar Project

Environmental product declaration
according to ISO 14025

Electricity generated in photovoltaic power plant

***El Romero Solar* 196 MW**

Version: 3.0
Publication date: 2017-12-12
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Validity date: 2026-03-31
Registration number: S-P-01081
Programme: The International EPD® System, www.environdec.com
Programme operator: EPD International AB

CPC 171 - Electrical energy
PCR 2007:08 UN CPC 171 & 173 - Version 4.11 - Electricity, steam and hot water generation and distribution

EPD®

acciona

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1. Introduction

1.1 Product and EDP System environmental declarations

This document contains a declaration of the environmental impact (EPD) of the power generated in the El Romero photovoltaic power plant in Chile, based on a Life Cycle Assessment (LCA). It also contains additional environmental information not based on the LCA according to the requirements of the relevant product category rules (PCR), including impacts on the biodiversity in the area, the use of land on the site, the main environmental risks, the electromagnetic fields generated, noise and visual impact.

An Environmental Product Declaration is defined in the ISO 14025:2010 standard as the quantifying of the environmental data of a product according to the categories and parameters specified in the ISO 14040 family of standards, including additional environmental information when relevant.

The main objective of the International EPD® System is its ambition to help and support organisations to communicate the environmental behaviour of their products (goods and services) credibly and understandably.

The system thus offers a complete programme aimed at any organisation interested in developing and communicating EPDs according to ISO 14025:2010 as well as supporting other EPD programmes (e.g., national, sectorial, etc), seeking their cooperation and harmonisation and helping the various organisations to encourage the use of environmental assertions in the international market.

Environmental Product Declarations add a new dimension to the market, offering public information on the environmental behaviour of the products and services. The use of EPDs brings a great number of benefits both for the organisations that develop them on their products and for those who use the information in them.

This EPD was prepared according to the rules of the International EPD Consortium. The International EPD® System is a system for the international use of Type III Environmental Declarations, in accordance with ISO 14025:2010. Both the system and its applications are described in the General Programme Instructions (GPI).

The documents on which this EPD is based are, in hierarchical order of relevance:

- Product Category Rules, PCR 2007:08 version 4.11 CPC 171 & 173: Electricity, Steam, and Hot Water Generation and Distribution.
- General Programme Instructions for Environmental Product Declarations, Ver. 3.01.
- ISO 14025:2010 - Type III environmental declarations.
- ISO 14040:2006 and ISO 14044:2006 on Life Cycle Assessment (LCA).

1.2

ACCIONA (Energy Division)

In the energy field, ACCIONA is a global renewable energies operator, the largest one in the world dedicated exclusively to clean energies not connected to the conventional electrical companies.

It produces clean, emissions-free power for seven million homes throughout the planet, thus contributing to progress towards a more sustainable energy system that favours development without putting the environment at risk.

The company carries out this task increasingly competitively thanks to a permanent commitment to innovation, aimed at increasing the efficiency of our technological solutions in areas such as the remote operation and maintenance of facilities, energy storage and grid integration, among others.

With 30 years' experience in the sector, ACCIONA is present in the main renewable technologies, covering activities involving the entire value chain – development, engineering and construction, operation and maintenance and the sale of energy.

All of this is joined by a global vocation with implementation in more than 20 countries on all continents, especially aimed today at the emerging markets with needs for sustainable solutions to drive their development.

Solvency, reliability, experience and a global dimension are essential aspects in our corporate profile that make us a leading renewables player as promoter, partner or supplier of services world wide.

In ACCIONA we are convinced that renewables are the technologies with the greatest growth expectations in the 21st century given that only these offer a sustainable economical, social and environmental solution to the energy required by the world to drive its development.

the business management system used by the Energy Division of ACCIONA is certified according to the following international standards:

- ISO 9001:2015
  Quality management systems.
- ISO 14001:2015
  Environmental management systems.
- OHSAS 18001:2007
  Occupation health and safety management systems.

1.3

Differences from previous versions

This document, is an update of version 2.0 of the Environmental Product Declaration of the energy generated in the "El Romero" photovoltaic power plant. The objective of this update, is to obtain the renewal for the Environmental Product Declaration (EPD) of this facility using information updated to the 2020-year situation.

Modifications made prior to this update:

- All the indicators used from the ecoinvent database, have been updated from version 3.2 to version 3.5.
- The amount of energy sold in the plant has been updated, using the actual energy generation that is already known until October 2019.
- The new electrical consumption of the plant, product of the voltage support required by the National Electrical Coordinator, has been included.
- The inverter failure rate has been increased by 10%, due to the wear of components due to the reactive power absorption required by the National Electric Coordinator.

Modifications made in current version:

- The amount of energy sold in the plant has been updated, using the actual energy generation that is already known until September 2020.
- The amount of energy consumed in the plant has been updated, using the actual energy consumption that is already known until September 2020.
- The format of the result tables has been modified, in order to be consistent with the last version of the PCR 2007:08 UN CPC 171 & 173 - Version 4.11 - Electricity, steam and hot water generation and distribution.
- The validity of the results is now changed to 5 years, as specified in the previously mentioned PCR 2007:08 UN CPC 171 & 173 - Version 4.11 - Electricity, steam and hot water generation and distribution.

1.4

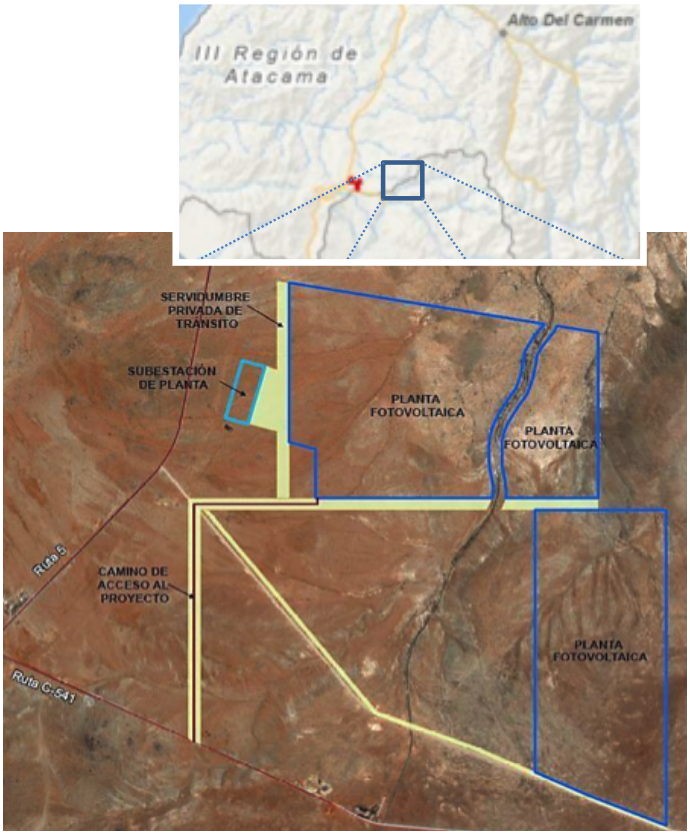
Functional unit

This document represents the certified Environmental Product Declaration for the energy generated in the El Romero photovoltaic power plant.

In this context, the functional unit is the reference that exactly defines the element being analysed and assessed from the environmental point of view in the declaration. All the information in this document is referenced to the functional unit, which in this case is:

"1 kWh net of electricity generated in the El Romero photovoltaic power plant that is then uploaded to a high voltage grid (220 kV) in Chile"

The amount of energy used as a reference flow was **11,802,827.428 MWh.** This reference flow represents the total net energy that the power station can generate over its **25 years' planned operation.** This reference flow is the value that allows the later referencing of all the inputs and outputs to the functional unit defined in the previous paragraph.



LEGEND

- Photovoltaic Plant
- Substation
- Private Transit Easement
- Access Road to the Project

1.5

Description of the product system analysed

The product system analysed is the El Romero solar photovoltaic power plant located in the Atacama desert in Chile. The project's area is in the Commune of Vallenar (province of Huasco) in Region III of Atacama (Chile), next to Route 5 and approximately 8 kilometres to the south of the hamlet of Cachiyuyo.

Its geographical location is latitude 29°6'35"S, longitude 70°54'31", also near the locality of Domeyko.

The plant has a **real area of 3,647,800 m²** occupied by the panels and other assets as well as a total of **601.18 hectares of leased area.**

El Romero has a peak **installed power of 246 MWp and a nominal power of 196 MW** using polycrystalline silicon photovoltaic panels. Construction on the site lasted from March 2016 to April 2017, with the milepost of connection to the grid and the start of the test phase occurring in mid-November 2016.

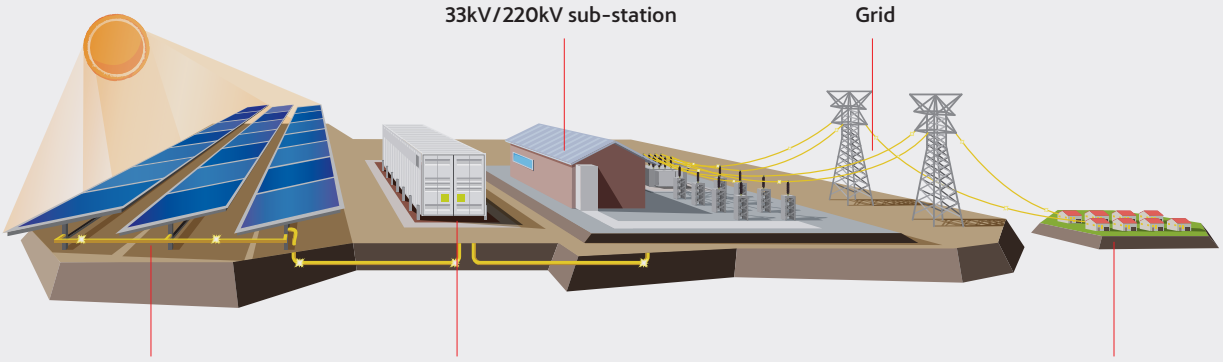
The sale of energy began at this time although the official date for the start of operation was March 2017.

The basic functioning of the power station can be divided into four areas, as shown in Figure 2. There is a first area with the photovoltaic panels where low voltage DC electricity is generated, a second area with the power stations in which the power is inverted to AC and stepped up to 33 kV, a third area containing the power station's output to the grid where the voltage is stepped up again to 220 kV and, finally, the energy sale point near the Don Héctor sub-station some 2.5 km away.

To achieve the suitable functioning of the site, it was necessary to install a set of equipment forming the photovoltaic power plant. The following describes in detail the main equipment in the El Romero solar power station.

Figure 1

El Romero Solar. Plant functioning schematic



Sunlight is converted into DC electricity by the **plant's solar panels.**

The DC power is transformed into AC power by the **inverters.**

The **transformers** raise the low voltage (415 V) to medium voltage (33 kV).

In the **sub-station,** the medium voltage is raised to high voltage (220 kV) for injection into the grid.

The power grid carries the power to the **consumers.**

PHOTOVOLTAIC PANELS

The photovoltaic panels or modules are the heart of any solar power station since they generate the energy in the system. Their task is to convert the sunlight falling on the panel into electrical current. The panels are formed of photoelectric cells connected together that can absorb the light photons and emit electrons, creating a continuous current.

This element is of great environmental relevance in the system due to the large number of panels installed in a power station with the power of El Romero and to the importance of their efficiency on the final environmental behaviour of the power station. Three types of photovoltaic panels were installed on the site. Their main properties are summarised in the following table.

Table 1

Photovoltaic Panels: Main characteristics

Panel	Technology	Unit power	Units installed	Ef [%]	Supplier	Origin
JAP6-72 315 4BB	Polycrystalline silicon	315 Wp	342.840	16,25	**JA Solar**	China
JAP6-72 320 4BB	Polycrystalline silicon	320 Wp	343.070	16,51	**JA Solar**	China
4BB_HR+315P	Polycrystalline silicon	315 Wp	90.320	16,27	**Hareon Solar**	China

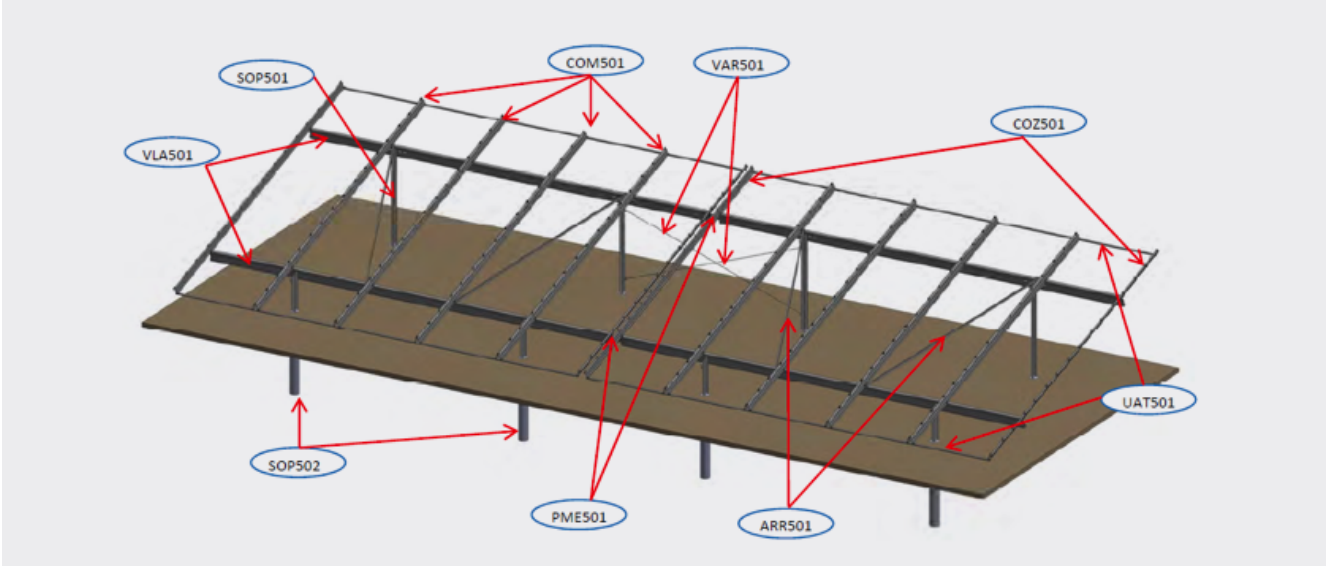
SUPPORT STRUCTURES

The structures that support the photovoltaic panels and protect them from the ground are of the fixed type in this site. As with the modules, the supports were provided by two companies, STI Norland and Krinner. Both structures are made mainly of galvanised steel.

Table 2

Support Structrures: Main characteristics

Support	Units installed	Angle	Capacity	Foundation	Supplier	Origin
ST-F5	9.691	17º	40 modules	Mixed	**STi Norland**	Spain
FLEX-V	4.362	20º	Varying between 30 and 90 modules	Steel studs	**KRINNER**	Germany



INVERTER STATIONS

Once the sunlight has been converted into low voltage DC electricity in the panels, it is carried by cabling to the inverter stations, of which there are 60 dispersed over the site. These inverter stations contain a set of electrical equipment to convert continuous electricity to alternating and then raise the voltage to reduce cabling losses as far as possible. The main items of equipment in the inverter stations are detailed in the following table.

Table 3

Inverter Stations: Main characteristics

Equipment	Total Units	Function	Supplier	Origin
PVS800 1200 kW INVERTER	180	Element that converts DC power generated by the modules to an AC signal.	**ABB**	Spain
TRANSFORMER VACUUM CAST COIL DRY TYPE 3600 KVA	60	Steps up the low voltage electricity to medium voltage.	**ABB**	Spain
MEDIUM VOLTAGE SWITCHGEAR SAFE PLUS SWITCHGEAR 36KV	60	Undertakes operating, metering, protection and/or control of the electricity.	**ABB**	Norway
UPS SYSTEM	60	Provides power for a limited time and during a power cut to the devices connected to it.	**ABB**	China

EL ROMERO ELECTRICAL SUB-STATION

After passing through the inverter stations, the electricity generated is carried by medium voltage underground cabling to an electrical sub-station built specifically in El Romero to deliver the energy generated to the general electrical transport grid.

Before leaving the photovoltaic power plant, the energy's voltage is stepped up again to 220 kV (HV) by the power transformer in the sub-station itself. The main equipment installed in the El Romero sub-station and that was also included in the system to be studied was the following.

Table 4

Electric Substation: Main characteristics

Equipment	Unit installed	Supplier	Origin
Power transformer	1	**SPECO**	China
HV isolator	2	**COELME**	Italy
Medium voltage switchgear	17	**MESA**	Spain
HV switch	1	**SIEMENS**	Germany
Protection, control and metering boards	1	**INGETEAM**	Spain
Lightning conductor	13	**CHINT**	China
MV isolator	1	**CHINT**	China
Auxilliary services reactance and transformer	1	**SCHAFFNER**	Chile
Current and voltage transformers	6	**ARTECHE**	Spain
Telecommunications equipment	6	**COLWAY**	Spain
Generator	1	**CUMMINS**	India
Batteries and chargers	184	**ZIGOR**	Spain
Auxilliary services boards	2	**TECMEL**	Chile
Generation switchgear	1	**SEIS**	Chile
Wave traps	3	**SIEMENS**	Brazil

Despite being outdoors, the sub-station also has its own control building housing the switchgear. The construction of this building was included in the scope of the project.

CONNECTION LINE TO THE GENERAL ELECTRICITY GRID

After reaching the El Romero electrical sub-station and converted to high voltage, the energy must be carried to the point of connection with the Chilean electricity grid, which in this case is relatively near the power station, in the Don Héctor sub-station, 2.5 km away.

An overhead high voltage power line was built for this purpose, consisting of the following elements.

Tabla 5

Connection Line: Main characteristics

Element	Units Installed	Supplier	Origin
Steel pylons	12	**BBOSCH**	Chile
AAAC Flint overhead aluminium cable	8.000 m	**Comercial Aragón**	Chile
OPGW 24 overhead cable	4.000 m	**Comercial Aragón**	Chile
E.H.S 3/8" overhead steel cable	520 m	**Comercial Aragón**	Chile
Optical fibre cable	345 m	**Comercial Aragón**	Chile
220KV underground cable	1.530 m	**NEXANS**	Spain

ADDITIONAL ELEMENTS

As well as all the elements in the photovoltaic system described in the above sections, there is a series of common elements that must also be considered when preparing an LCA for a plant of this type. This refers to all the cabling elements, grouping boxes, connectors, auxiliary control and storage buildings, communication masts and perimeter fence.All these additional elements form part of the life cycle of the El Romero power station and have been considered for preparing the study.

Tabla 6

Additional elements

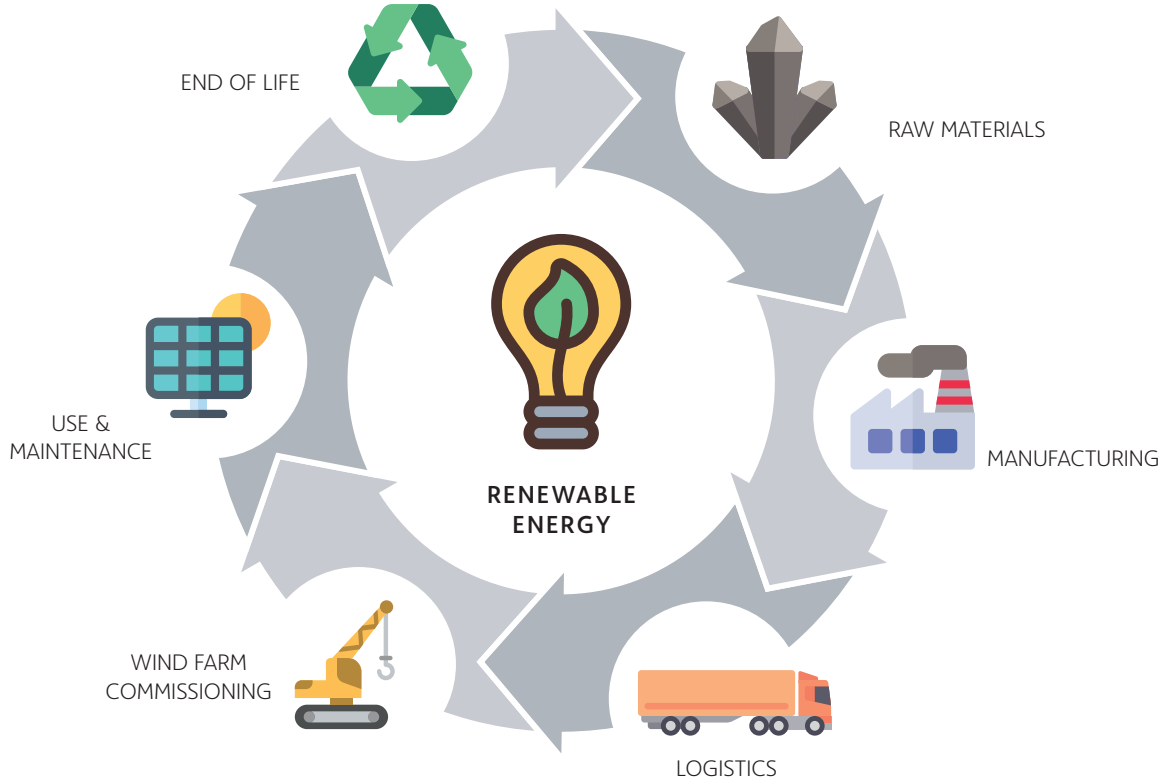
Equipment	Quantity installed	Unit	Supplier	Origin
DC connectors (LV)	13,484	units	**AMPHENOL**	Tunisia
DC cabling (LV)	702,903	m	**POLYCAB**	India
AC Cabling (MV)	119,524	m	**HENGTONG**	China
Optical fibre	40,390	m	**OPTRAL**	Spain
Earthing system	52,490.4	m	**NEXANS**	Chile
Drilling connectors	13,705	units	**NILED**	Spain
Grouping boxes	1,568	units	**CHEMIK**	Spain
Trays	2,001	units	**BASOR**	Spain
Perimeter fence	19,099	m	**HEC**	Chile
Communications mast	1	units	**RAYTECH**	Chile
Auxiliary buildings	4	units	**QUANTA/SARPEL**	Chile

2. Environmental information based on LCA

2.1 Limits of the system assessed

This EPD is based on an exhaustive analysis of the life cycle of the energy generated in El Romero, which is distributed to a high voltage Chilean grid. Because of this, the environmental impacts declared include the entire life cycle of the photovoltaic energy from cradle to grave.

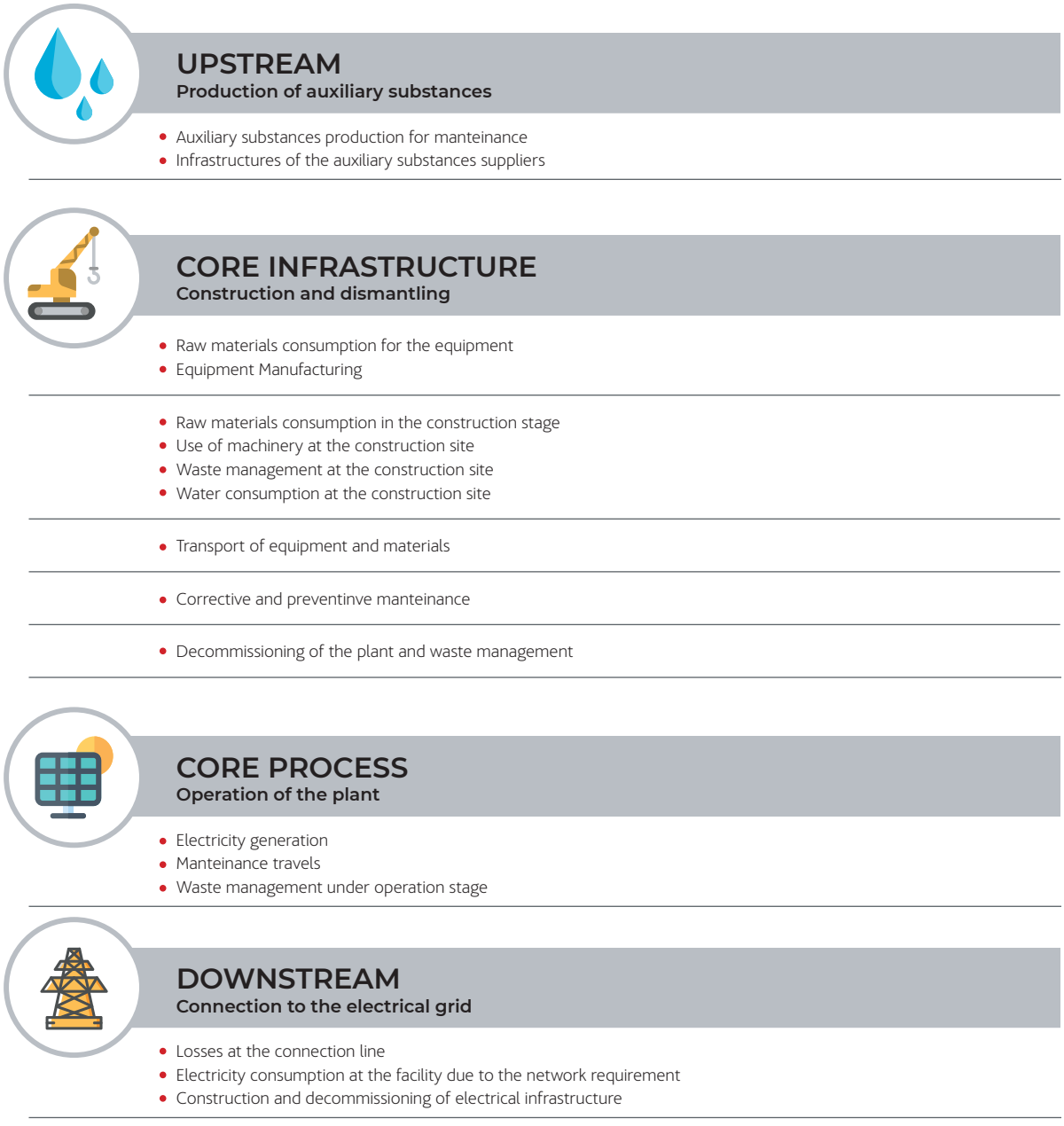
Figure 2
The life cycle of the energy generated in El Romero



As required in the reference PCR, the complete life cycle has been divided into three large blocks to be able to clearly define the limits of the system assessed. These blocks are called upstream, core and downstream. In addition, the core and downstream blocks have in turn been split into the "process" and "infrastructure" subdivisions.

The following figure shows the limits of the system assessed.

Figure 3



The data used to create the LCA model in the Simapro 9 software were obtained directly by ACCIONA or by its suppliers. It is this information that ensures that the declared results match the reality of the equipment installed in El Romero. The data used to create the LCA model are fully traceable and were reviewed during the external audit process to verify the EPD.

ACCIONA's objective was to include all the available information in the Life Cycle Assessment. At the end of the study, environmental information on 99.98% of the total mass flows of the photovoltaic power station was included.

Table 7
El Romero photovoltaic power plant

Group	Theoretical total [kg]	Total analysed [kg]	% Compiled
Photovoltaic system	32.677.193,69	32.677.103,69	100,00%
Common elements	8.765.474,57	8.761.907,79	99,96%
Electrical sub-station	296.147,28	292.433,89	98,75%
Grid connection line	103.573,43	103.573,43	100,00%
TOTAL	**41.842.388,97**	**41.835.018,80**	**99,98%**

Starting with these primary origin data, the Ecoinvent 3.5 database was used to prepare the LCA model. Ecoinvent is the life cycle inventories database most widely-used world wide and contains consistent and transparent information. This database contains industrial level life cycle inventories on energy sources, resources extraction, provision of materials, chemicals, metals, agriculture, wastes handing services and transport services, among others.

Likewise, in the verification audit it was found that less than 10% of the environmental impact came from values with a low quality level, also called "proxy."

The following sections detail the elements included in each block in the study, giving greater emphasis on the data sources and on their geographical and time validity.

2.1.1 UPSTREAM

The "upstream" module considers all the environmental impacts relating to the manufacture of auxiliary substances needed for the correct operation of El Romero throughout its 25 years of operation.

Given that solar photovoltaic energy requires no fuel for its functioning, this module includes consideration of only the main needs for substances that must be consumed during the preventive maintenance stage and their transport to the power station's location.

The ACCIONA Operation and Maintenance Department has defined a series of operational instructions that describe the main actions to be undertaken during this stage in the power station. These maintenance instructions are the main source used for the requirement for consumables. In this case, the needs for water for periodically cleaning the panels, the need for cleaning the meteorological stations and the maintenance of the sub-station generator have been considered.

2.1.2 CORE – INFRASTRUCTURE

The "core-infrastructure" module strongly represents the greatest part of the life cycle of the energy generated in El Romero, including all the stages relating to the construction and decommissioning of the El Romero photovoltaic power plant. All the impacts relating to the obtaining of raw materials, the manufacture of the equipment installed, its transport to Chile, the work of constructing the site and its final decommissioning form part of this "core-infrastructure" module.

After the decommissioning of the power station, a series of items of equipment and materials appears that will have to be handled appropriately as wastes. The transport of these wastes to their final destination and the environmental impact of their handling also form part of the "core-infrastructure" module.

This module also includes the expected needs for corrective maintenance in the plant, including the re-investment in faulty equipment according to its estimated failure rates.

All the data used for the El Romero LCA were compiled in the period February 2016 – May 2017, simultaneously with the construction of the site and are today considered fully representative of the reality of the photovoltaic power plant throughout its 25 years of operation. A check will be made in the periodic reviews of the LCA that the representativeness over time of the critical data in the study continues to remain at a suitable level.

MANUFACTURE OF EQUIPMENT INSTALLED AND TRANSPORT TO EL ROMERO

During the life cycle inventory preparation stage, in which the necessary information on the equipment installed in El Romero was compiled, the relevant information was requested from all the suppliers involved. These equipment suppliers provided ACCIONA with all the necessary information for preparing the power station's LCA model, including data on inventories of materials, breakdown of weights, specific Life Cycle Assessments of their products, detailed drawings, technical specifications, safety records and information on consumptions during the manufacturing process.

This included the suppliers of the photovoltaic panels, the support structures, the cabling and connection elements and the equipment in the inverter stations and the sub-station.

The information compiled for these items of equipment faithfully represents the technology installed in El Romero so that the results must be considered representative of their life cycle as long as the equipment installed is not substantially modified.

For the logistics stage, the distances really travelled by each item of equipment from its supplier to El Romero were analysed, also taking into account the transport means used. This information was obtained from the delivery note for each item of equipment provided by the ACCIONA Purchases Department and from the embarkation record in the same department.

CONSTRUCTION WORK AND INSTALLATION OF THE SITE

Information on the environmental aspects in the site construction phase such as materials consumption, fuel consumption, water consumption and the handling of the wastes generated was collected on site by the ACCIONA Chile team and the sub-contractors involved in the work during the period of the construction of El Romero. Thanks to this effort, the results of the environmental impact are a faithful representation of the technological systems used for this stage in El Romero.

DECOMMISSIONING AND WASTES HANDLING

The stage of the decommissioning and end of life of El Romero is planned for 2042. It is evident that, despite the planning by ACCIONA for undertaking this task, the possible modification in the wastes treatment systems of legislation in the matter in Chile requires us to pose a theoretical destination for the wastes that will be generated in this stage.

To estimate the end of life of all the materials and equipment that will be converted into waste after the decommissioning of El Romero, the "Description of the abandonment state" chapter in the EIS (Environmental Impact Statement) prepared by ACCIONA before beginning the installation work was used as the starting point. In addition, to include the specific regional aspects on the problem of wastes handling in Chile in theory, the "First report on the handling of solid wastes in Chile." published in 2010 by the National Environment Commission of the Government of Chile, was consulted. Likewise, to calculate the environmental impact of transporting all these wastes to each authorised handler, the current distance between El Romero and the

main wastes handling options in the area today have been estimated.

For the project abandonment stage, all the current legal and environmental requirements will be met. The mechanical and other unused elements will be removed and transferred for re-use, recycling or deposited in the place authorised for it according to the current regulations. After dismantling the equipment in the El Romero solar power station, the previously occupied areas will be restored.

A destination for each of the elements in the power station has been considered. For more information, the following table contains the theoretical end of life for the main elements in El Romero.

Table 8

Theoretical end of life for the main elements in El Romero

System	End of life theory
Photovoltaic panels	The panels will be disconnected and dismantled manually. The modules in operating conditions will be re-used while the rest of the components will be recycled.
Support structures	The supports are all steel so that after their dismantling and storage they will be transported to a recycling centre. Half of the STI supports have a concrete micro pile which will be demolished and transported to a tip as inert material.
Inverters	The steel parts of the inverters will be recycled completely. The electronic components will be sent to a WEEE handler for their appropriate dismantling and handling. The rest of the materials will be handled via a tip.
Cells	The metal components (mainly copper and steel), the SF6 and the oil will be recovered and recycled safely. The rest of the materials will be handled via a tip.
Transformers	The metal parts of the transformers can be separated and recycled. The resins, plastics and other materials will be handled via a tip.
UPS	To be sent to a waste electrical and electronic equipment (WEEE) handler.
Inverter stations containers	The containers are all steel and therefore will be recycled.
Inverter stations foundations stations	It is assumed that the concrete blocks in the inverter stations will be demolished and removed to an authorised inert wastes tip.
Sub-station power transformer	The metal parts of the transformers can be separated and recycled. The transformer oil will be recovered and recycled as a hazardous waste. The rest of the materials such as the porcelain, insulation paper and plastics will be handled via a tip. It is assumed that the concrete blocks of the sub-station equipment foundations will be demolished and removed to an authorised inert wastes tip.
Internal cabling	After dismantling, the cabling elements will be sent for specific cables treatment, which includes the separation of the conductors from the insulation layers. The metal conductors will then be recycled while the plastic insulation materials will be incinerated.
Auxiliary buildings	After the buildings are dismantled, the steel parts will be stored and then recycled. It is assumed that the buildings' foundation will be dismantled for taking to a tip. The rest of the materials such as ceramics, plastics, concrete blocks, etc, will be handled via an authorised tip.
Connecting line to grid	The power line pylons are entirely steel so that they will be sent for recycling after dismantling. After dismantling, the cabling elements will be sent for specific cables treatment, which includes the separation of the conductors from the insulation layers. The metal conductors will then be recycled while the plastic insulation materials will be incinerated.

2.1.3 CORE – PROCESS

The "core-process" module represents the operation stage of El Romero. As well as including the equipment's technical functioning properties such as output, efficiency and the amount of energy they can obtain from the Sun, it also includes the maintenance journeys to be made by the workers undertaking it during the service life of the power station as well as the appropriate handling of the wastes generated during its 25 years of operation.

One of the critical factors of the analysis of El Romero is the energy that the power station will be able to generate throughout its operational period. It is estimated that the service life of the site will be 25 years, which is the time for which its operation licence lasts, but really its functioning period is slightly longer, 25 years and 5 months.

The power station started to export power in the test phase in mid November 2016. However, commissioning in the operation phase did not occur until March 2017. Therefore, the life cycle of El Romero Solar runs from November 2016 to the end of March 2042 (25 years and 5 months), which is when the operation licence expires.

To calculate the amount of energy generated during these years of operation, this period has been divided into sections depending on the source from which the data have been obtained.

Table 9

Data sources for energy generation

Period	Time	Data source
November 2016 – September 2020	3 years and 11 months	Real data for the energy generated
October 2020 – March 2042	21 years and 6 months	Estimate

The data that refer to the output of the installation and the energy generated have been provided by the ACCIONA Photovoltaic Resource Department and is the best information available on the energy that El Romero can generate in the future 25 years for which its operation is planned. In total, it is anticipated that the power station will be able to generate 11,802,827.428 MWh of power throughout its service life, of which 11,791,024.601 MWh will reach the Chilean electricity grid after deducting the losses in the power transport grid.

To represent the reality of the environmental behaviour of El Romero more reliably, it is planned to revise the LCA every five years to include the plant's real generation in this period once this is a known value.

The information used to simulate the workers' maintenance journeys includes the journeys in 4x4 vehicles from La Serena and from Vallenar to El Romero, and an estimate of the internal movements of the vehicles in the plant. The fuel consumed has been calculated with an estimate from ACCIONA based on the proposed preventive maintenance.

2.1.4 DOWNSTREAM

Finally, the "downstream" stage covers all the impacts that occur from the moment at which the energy leaves the El Romero sub-station transformer until it arrives at the connection point with Chilean electricity grid at 220 kV, located in the neighbouring Don Héctor sub-station.

This downstream module represents two separate impacts. The first is the environmental impact relating to the inevitable power losses that occur in the line connecting El Romero with Don Héctor, caused by the voltage step-up and the Joule effect. This first impact is called specifically "downstream – process" in the context of the EPD.

The second environmental impact is associated with the construction and dismantling of the power line connecting the El Romero sub-station to the Don Héctor sub-station. This second impact is called "downstream – infrastructure."

The high voltage overhead power line that had to be built has a total length of 2.5 km and allows the power generated in the power station to be delivered to the Chilean electricity grid. It should be noted that a simulation was made of the system really built, including the cabling and pylons, with information provided by the suppliers. The power losses in this line were considered by the ACCIONA Solar Resource Department to be 0.1% of the total energy generated in El Romero.

Finally, El Romero photovoltaic plant is also giving support to the stability of the Chilean electricity grid, based on the provisions of the Technical Standard for Safety and Quality of the Service of the National Energy Commission, which governs the operation of the electrical system in this country. To contribute to the stability of the system, El Romero plant is forced to have a constant energy consumption during the night hours, product of the voltage support required by the National Electrical Coordinator. This consumption occurs because of the absorption of reactive power to the maximum level declared by the plant almost permanently. This fact is causing an electricity consumption at the plant, which has also been considered as an environmental aspect for the life cycle analysis, within this same downstream module.

2.2 Environmental profile

The following tables contain the environmental behaviour of the energy generated in the El Romero photovoltaic power plant from a complete life cycle perspective. The results have been calculated underthe methodology CML-IA v 4.8 – August 2016, and they have been divided into columns according to the stages described in the previous sections. The EPD verifier had detailed access to Life Cycle Assessment information that supports this declaration.

It is important to remember that the functional unit to which all the values in the tables refer, is:

> *"1 kWh net of electricity generated in the El Romero photovoltaic power plant that is then uploaded to a high voltage grid (220 kV) in Chile"*

Table 10

Environmental profile of the photovoltaic plant El Romero

Environmental profile	Unit	El Romero 196 MW photovoltaic power plant						
Potential environmental impact		1 kWh of electricity generated and distributed to a consumer at 220 kV						
		Upstream	Core process	Core infrastructure	TOTAL GENERATED	Downstream process	Downstream infrastructure	TOTAL DISTRIBUTED
POTENTIAL ENVIRONMENTAL IMPACT								
Global warming potential (100 years):								
▷ Fossil	g CO_2 eq	1,10E-02	4,99E-01	1,85E+01	**1,90E+01**	9,99E+00	2,63E-02	**2,91E+01**
▷ Biogenic	g CO_2 eq	1,06E-05	7,31E-05	1,56E-01	**1,57E-01**	2,81E-03	6,34E-05	**1,59E-01**
▷ Land use and transformation	g CO_2 eq	5,84E-06	4,27E-05	2,08E-02	**2,08E-02**	6,74E-04	6,23E-05	**2,15E-02**
▷ TOTAL	g CO_2 eq	1,10E-02	4,99E-01	1,87E+01	**1,92E+01**	1,00E+01	2,64E-02	**2,92E+01**
Formation potential of tropospheric ozone	g NMVOC eq	1,45E-04	6,91E-03	8,26E-02	**8,96E-02**	4,92E-02	1,30E-04	**1,39E-01**
Acidification potential	g SO_2 eq	1,14E-04	4,83E-03	1,38E-01	**1,43E-01**	7,32E-02	3,36E-04	**2,17E-01**
Eutrophication potential	g PO_4^{-3}-eq	2,40E-05	8,80E-04	6,36E-02	**6,45E-02**	2,69E-02	1,63E-04	**9,16E-02**
Abiotic depletion potential. Elements	g Sb eq	2,38E-08	1,68E-07	1,29E-03	**1,30E-03**	1,01E-05	3,01E-06	**1,31E-03**
Abiotic depletion potential. Fossil fuels	MJ, net calorific value	1,47E-04	7,22E-03	1,98E-01	**2,05E-01**	1,21E-01	3,05E-04	**3,26E-01**
Water scarcity potential	m^3 eq	9,64E-05	3,32E-05	6,36E-03	**6,49E-03**	5,29E-04	1,17E-05	**7,03E-03**

Table 11

Use of resources of the photovoltaic plant El Romero

Environmental profile	Unit	El Romero 196 MW photovoltaic power plant						
Use of resources		1 kWh of electricity generated and distributed to a consumer at 220 kV						
		Upstream	Core process	Core infrastructure	TOTAL GENERATED	Downstream process	Downstream infrastructure	TOTAL DISTRIBUTED
RENEWABLE RESOURCES								
Used as energy carrier	MJ, net calorific value	4,23E-06	4,22E-05	2,04E-02	**2,04E-02**	2,63E-02	3,05E-05	**4,67E-02**
Used as raw materials	MJ, net calorific value	0,00E+00	0,00E+00	6,35E-05	**6,35E-05**	6,35E-08	0,00E+00	**6,36E-05**
TOTAL	MJ, net calorific value	4,23E-06	4,22E-05	2,05E-02	**2,05E-02**	2,63E-02	3,05E-05	**4,68E-02**
NON-RENEWABLE RESOURCES								
Used as energy carrier	MJ, net calorific value	1,53E-04	7,29E-03	2,10E-01	**2,17E-01**	1,21E-01	1,21E-04	**3,38E-01**
Used as raw materials	MJ, net calorific value	2,01E-07	0,00E+00	5,19E-03	**5,19E-03**	5,19E-06	2,10E-04	**5,41E-03**
TOTAL	MJ, net calorific value	1,53E-04	7,29E-03	2,15E-01	**2,22E-01**	1,21E-01	3,31E-04	**3,44E-01**
OTHER RESOURCES								
Secondary material	Kg	0,00E+00	0,00E+00	6,44E-04	**6,44E-04**	6,44E-07	3,94E-06	**6,49E-04**
Renewable secondary fuels	MJ, net calorific value	0,00E+00	0,00E+00	0,00E+00	**0,00E+00**	0,00E+00	0,00E+00	**0,00E+00**
Non-renewable secondary fuels	MJ, net calorific value	0,00E+00	0,00E+00	0,00E+00	**0,00E+00**	0,00E+00	0,00E+00	**0,00E+00**
Net use of fresh water	m^3	2,21E-06	1,00E-06	1,79E-04	**1,82E-04**	1,94E-05	3,29E-07	**2,02E-04**

Table 12

Waste handling and outplut flows of the photovoltaic plant El Romero

Environmental profile	Unit	El Romero 196 MW photovoltaic power plant						
Waste handling and output flows		1 kWh of electricity generated and distributed to a consumer at 220 kV						
		Upstream	Core process	Core infrastructure	TOTAL GENERATED	Downstream process	Downstream infrastructure	TOTAL DISTRIBUTED
WASTE PRODUCTION								
Hazardous waste disposed	Kg	1,44E-10	3,25E-09	2,20E-06	**2,20E-06**	5,20E-08	1,17E-08	**2,27E-06**
Non-hazardous waste disposed	Kg	6,34E-07	7,95E-06	4,02E-03	**4,02E-03**	6,89E-04	7,32E-06	**4,72E-03**
▷ Ash	Kg	2,52E-08	1,78E-07	6,09E-05	**6,11E-05**	6,59E-06	1,19E-07	**6,78E-05**
▷ Inert waste	Kg	6,09E-07	7,77E-06	3,95E-03	**3,96E-03**	6,83E-04	7,20E-06	**4,65E-03**
Radioactive waste disposed	Kg	8,95E-10	5,06E-08	5,47E-07	**5,98E-07**	1,76E-07	7,79E-10	**7,75E-07**
OUTPUT FLOWS								
Components for reuse	Kg	0,00E+00	0,00E+00	0,00E+00	**0,00E+00**	0,00E+00	0,00E+00	**0,00E+00**
Material for recycling	Kg	0,00E+00	1,17E-05	2,70E+00	**2,70E+00**	2,70E-03	8,78E-03	**2,71E+00**
Materials for energy recovery	Kg	0,00E+00	0,00E+00	0,00E+00	**0,00E+00**	0,00E+00	0,00E+00	**0,00E+00**

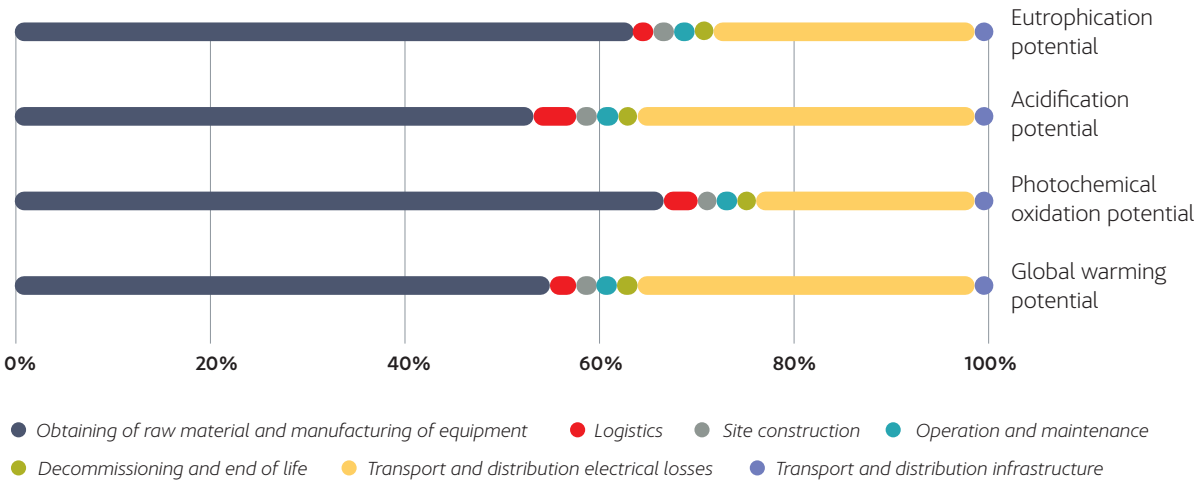
2.3

Interpretation of the results and conclusions

To be able to identify the aspects causing the environmental impacts declared in the previous section, a view is needed of each of the stages in the complete life cycle of the energy generated in El Romero from an integral perspective.

Figure 4

Distributed energy in El Romero Solar



As can be seen in the above figure, the environmental profile is clearly dominated by the stage of obtaining raw materials and manufacturing the equipment, as well as by the power losses in the electrical transmission line. The first of these two stages, accounts for between **55.3%** and **68.7%** (according to the category analysed) of the total environmental impact of each kWh generated in El Romero.

The photovoltaic panels stand out as the main environmental aspect in this stage, with an impact much higher than that caused by the support structures, which form the second most important aspect. This is a logical result, given that the panels are the main asset by volume installed in El Romero.

The rest of the environmental impact not caused by the stage of obtaining raw materials and manufacturing the equipment is mainly caused by the power losses in the electrical distribution line. This stage has an environmental impact ranging from **23.1%** to **34.2%** (depending on the category analysed). This is caused by the energy consumption that the plant is forced to undertake to absorb reactive power during the night hours, at the request of the National Energy Commission.

Regarding the other stages of the life cycle, the logistics stage represents between **1.5%** and **5.7%** (depending on the category analyzed) of the total environmental impact. This impact is caused by the transport of the equipment to the plant, while the project materials transport stage has a much lower repercussion, almost negligible.

The next most important stage is that of operation and maintenance with **2.4%** impact on average, between the four categories analyzed. There are two elements in this stage that stand out mainly, the consumption of fuel associated with the maintenance journeys during the 25 years of operation and the corrective maintenance of the plant. The environmental impact of the corrective maintenance is in turn dominated by the need to change deteriorated photovoltaic panels throughout the service life of El Romero.

On the other hand, the site construction stage has an environmental impact that varies between **1.3%** and **1.8%** of the total. This result can be considered relatively low, considering that a normal trend in the analysis of renewable energy power plants is that their construction has a notable impact. This stage is mainly dominated by the emission of air pollutants associated with the consumption of Diesel fuel by the machinery.

The two remaining stages are the decommissioning and end of life of the assets, and the power line infrastructure. Each of these three stages has an environmental impact of **less than 1%** on average for the four environmental impact categories.

3. Additional environmental information

3.1

Biodiversity protection

The implementation of solar energy as an alternative to other traditional power generation options has evident benefits for the environment. However, the installation of a site of this type in a natural enclave such as the Atacama desert must be undertaken with great care to protect the biodiversity in the area.

With this idea in mind, before starting the El Romero Solar project, ACCIONA undertook a series of studies aimed at protecting the natural species in the chosen location, thus ensuring that the effect of the work was minimised.

GUANACO CONSERVATION PLAN

The ACCIONA El Romero solar photovoltaic project is located in the Commune of Vallenar, Region of Atacama. The main wildlife species that inhabit the area can be divided into mammals and reptiles.

The presence of six taxons of mammals was detected, of which the guanaco is the sole wild species.

ACCIONA acquired the environmental commitment to implement actions that contribute to the conservation of these populations in the area in which the project is located through a Guanaco Conservation Plan.

The monitoring implemented in the area will help to generate information on the current state of the populations and, together with other conservation actions, to reduce the threats to the camelidae and other wildlife in the area.

REPTILES RESCUE AND RELOCATION PLAN

Regarding the population of reptiles in the area, a reptiles rescue and relocation plan was been undertaken to avoid any impact to the land vertebrate wildlife component, safeguarding the genetic profile and the biodiversity of the reptiles and amphibians in the sector.

Generally, the rescue plan is aimed at those reptile species detected in the Project Baseline, Liolaemus atacamensis (Atacama tree iguana), Liolaemus platei (braided tree iguana) and Callopistes maculatus (spotted false monitor).

The examples collected were deposited in gender bags with a maximum of three individuals in each bag or recipient. The permeability of the bags allowed air to enter, reducing the risk of the death of specimens. The routine handling aspects included the frequent checking of the health of the captured individuals.

Aspects such as weight, size, gender and specific identification were recorded. After recording these, the examples were relocated in the relocation area. A total of 486 individuals was rescued and relocated - 373 of L. atacamensis, 106 of C. maculatus and seven of L. platei. All of these examples were freed in good conditions in the project relocation area.

Land wildlife rescues are an important and practical scientific challenge for Chile. The background and assessments of these procedures are very scarce nationally.

BIOLOGICAL MANAGEMENT PLAN

As required during the environmental assessment process for the project, a Biological Management Plan was presented, the environmental commitments of which can be grouped into two blocks.

One comprises an action plan that includes the set of environmental actions and measures to be carried out during the project construction and operation phases and the other, environmental management measures to be implemented to compensate for the effect on plant species in the conservation category in the project area and the restoration of the plant life once the project reaches the end of its service life.

The bushy shrubs in the project area lie mainly in areas with little gradients, poor soil consisting mainly of gravel and very stony. The plant life is dominated by bushy shrubs (low woody content) with an average height that does not exceed one metre and a coverage ranging from 5% (very scarce) to sectors with 10% (scarce). The most common and frequent species in this type of unit are Bulnesia chilensis, Adesmia argentea, Krameria cistoidea, Cordia decandra, Cumulopuntia sphaerica, Encelia canescens and Haplopappus rigidus.

The action plan considers two fronts for protecting the plant life in the area in which the project is inserted.

The following table contains the measures taken for both the fronts differentiated previously to achieve a suitable protection of the plant life in the project area.

Table 13

Biological management and prevention measures.

PREVENTION MEASURES
Induction talks for workers, contractors and sub-contractors
Definition of restricted areas in the project
Layout of works
BIOLOGICAL MANAGEMENT MEASURES
Definition of target species in the Biological Management Plan
Construction of an exclusion area with perimeter fence
Procedure for rescuing and re-locating cacti
Procedure for rescuing germplasm, nursery techniques and planting of bush species
Procedure for rescuing and re-locating bulbs
Restitution procedure for the project abandonment stage

3.2
Use of land

The area on which El Romero Solar lies is a desert area that could be described as an arid plain. The total area delimited by the project is 601.18 hectares of which 236.4 will remain unaffected after the construction of the site.

Table 14
Corine Land Cover Classes

Corine land cover classes	Area of land occupied (m2)	
	Before the proyect	After construction
Artificial areas	Not applicable	**3,647,800**
Agricultural areas	Not applicable	Not applicable
Wooded and semi-natural areas	**6,011,800**	**2,364,000**
Wetlands	Not applicable	Not applicable
Masses of water	Not applicable	Not applicable

The areas in which construction has modified their initial classification are now occupied by the following elements:

- Photovoltaic panels.
- Steel containers for the inverter stations.
- Electrical transformer sub-station.
- Control and storage buildings.
- Tracks and roads.
- Power line pylons.

It should be noted that after the project decommissioning stage, planned for 2042, it is intended to restore all the affected areas of land to their original state.

3.3
Environmental risks

ACCIONA undertakes an analysis at the corporate level of the possible environmental risks that may occur accidentally in its projects to be able to classify their potential seriousness.

It is thus possible to act before the occurrence of an unexpected event to minimise both the frequency of the possible risks and their possible effect on the natural environment.

A multi-disciplinary human team was formed to prepare the list of possible accidental environmental scenarios that considered the following aspects.

- Area of the installation affected.
- Source of the danger.
- Initiating event.
- Environmental vector affected.
- Product involved and quantity.
- Measures available to reduce the risk.

Both the corporate standard and the internal procedure used indicate that the risk must be assessed by multiplying two factors, probability (forecast frequency of the accident scenario) and consequences (in environmental terms).

Of the 10 accident scenarios assessed, nine have a "Low" risk level according to the risks matrix. Only one of them has a "Moderate" risk level, mainly due to its probability of occurrence, this being scenario 7 (Spillage of Diesel fuel from the panel washing tractors, polluting the ground).

With this analysis, it can be concluded that El Romero is an installation with a low environmental risk.

3.4

Electromagnetic fields

Regarding electromagnetism, the values of the electrical and magnetic fields associated with the high voltage power lines built for the project have been estimated. The noise and interference levels generated by these transmission lines were also estimated, for both AM radio and TV transmissions. All of this sought to set a baseline for electromagnetic fields in the area in which the ACCIONA project is located.

Once these values had been estimated, they were compared with the maximum values recommended in the international reference standards to determine the possible effect of the existing lines on both human health and radio communications.

As a result of comparing the values obtained for the project with the recommended levels, it can be concluded that both the electromagnetic field and the radio and TV interferences that will be generated by the operation of the connection line will not exceed the recommended limits, even considering the effects with the existing lines together.

Taking the above into account, it can be stated that there are no risks to the population's health from the electrical and magnetic fields that will be generated by the project in its operation stage and neither will there be important alterations in the quality of radio and TV communications.

3.5

Noise

Supreme Decree 38 of 2011 of the Chilean Ministry of the Environment sets the maximum permitted levels for equivalent continuous sound pressure and the technical criteria for assessing and classifying the emission of annoying noise generated for the community by fixed sources.

The level of the noise generated in El Romero is at all times below these legally set limits. The following describes the main sources of noise throughout the project's life cycle.

CONSTRUCTION STAGE

The construction work increased the sound pressure levels around the project site, mainly due to the use of site machinery. This increase was due to the work itself (earthmoving, materials transport, machinery movement). In any case, because of the absence of nearby receivers, the emissions of this type were not considered relevant for this stage. It should be noted that the nearest populated centre is Cachiyuyo, located approximately 8 km from the project.

OPERATION STAGE

No noise emissions will be generated in the operation stage due to the nature of the project. There will be only noise from small vehicles for maintenance and surveillance activities.

DECOMMISSIONING STAGE

During the El Romero decommissioning phase, the main sources of sound pressure will be the use of machinery during disassembly and earthmoving and the movement of trucks on the access tracks. Since the operations are similar to those in the construction stage, the noise emissions for this stage are not considered a relevant aspect.

3.6

Visual impact

The project area is located in a relatively flat desert area but with low visibility and without special or outstanding elements. Its features and structure are those of the landscapes in the area. The permanent observers are drivers on Route 5 and Route C-541leading to the La Silla observatory.

Before the start of the work, a complete analysis was made of the site to identify, classify and assess the landscape reality of the spaces that would be affected in the project area. This classification was based on three concepts:

- Landscape quality.
- Landscape fragility.
- Visibility or visual basin.

Based on the quantitative values obtained after this classification, it is possible to classify the project areas according to the method proposed by Ramos (1980).

According to the results observed in the prior assessment, it is possible to determine that the landscape unit affected by the project can be defined as “arid plain” with low visual quality and average visual fragility, being classified as a class 4 landscape.

At the same time, after repeating the assessment including the project elements, the new visibility class obtained was identical to that obtained before the work started (class 4).

Finally, so that the end users can appreciate at first hand the visual effect caused in the area by the El Romero power station in the area, ACCIONA has created a visual bird’s-eye visit of the plant, available at the following link.

https://www.acciona-energia.com/areas-of-activity/photovoltaic/major-projects/el-romero-solar-pv-plant/

4. Information on the verification and contact

4.1 Information on the verification

Table 15

EPD Programme	EPD International AB Box 210 60, SE-100 31 Stockholm, Sweden www.environdec.com
Registration number	S-P-01081
Publication date	2017-12-12
Review date	2021-03-31
Validity	2026-03-31
Geographical validity of the declaration	This declaration is valid for the El Romero photovoltaic power plant in Chile
Scope of the declaration	From cradle to grave
Independent verification of the data and declaration, as per ISO 14025:2006	⊗ EPD external verification ◯ EPD process certification
External verifying organisation	Tecnalia R&I Certificación, S.L. Verifier: Maria Feced info@tecnaliacertificacion.com
Verifying organisation accredited or approved by	ENAC. Acreditation number 125/C-PR283
LCA study undertaken by	IK Ingenieria
Reference product category rules (PCR)	PCR 2007:08 UN CPC 171 & 173 Version 4.11 Electricity, steam and hot water generation and distribution
PCR review conducted by	The Technical Committee of the International EPD® System A full list of members available on www.environdec.com The review panel may be contacted via info@environdec.com PCR review chair: Claudia A. Peña
PCR prepared by	Technical Commitee of the International EPD® System PCR moderator: Mikael Ekhagen - VATTENFALL Mikael.ekhagen@vattenfall.com
Procedure for follow-up of data during EPD validity involves third party verifier:	⊗ Yes ◯ No
Name of the company and contact	Acciona Energía, S.A. Av. Ciudad de la Innovación, 5 - 31621 Sarriguren, Navarra (España) Phone number: +34 948 00 60 00 e-mail: peio.izcue.basail@acciona.com www.acciona-energia.com

4.2 Additional clarifications

- Neither the verifier nor the program operator is responsible for the legality of the product.
- Environmental Product Declarations of the same product category but different programmes may not be mutually compatible.
- In accordance with the reference PCR, the stage of the use of the electricity has been omitted, given that it may have various functions in different contexts
- The Links and references section contains sources to obtain additional material on the methods used.
- The EPD owner has the sole ownereship, liability and responsibility of the EPD.

5. Links and references

Energy Division of Acciona Spain
www.acciona-energia.com

Energy Division of Acciona Chile
www.acciona.cl

"El Romero" photovoltaic power plant
www.acciona-energia.com/es/areas-de-actividad/fotovoltaica/instalaciones-destacadas/planta-fotovoltaica-el-romero-solar/

International Organization for Standardization
www.iso.org

Ecoinvent centre
www.ecoinvent.org

Institute of environmental science / Leiden University
www.cml.leiden.edu

International EPD system
www.environdec.com

Impact methods and classification factors used
http://www.environdec.com/en/The-International-EPD-System/General-Programme-Instructions/Characterisation-factors-for-default-impact-assessment-categories/

General Programme Instructions for the International EPD System v3.01
https://www.environdec.com/contentassets/95ee9211a9614f1faa7461ff32cecc91/general-programme-instructions-v3.01.pdf

Environmental product declaration

according to ISO 14025

Electricity generated in photovoltaic power plant

***El Romero Solar* 196 MW**

Version: 3.0
Publication date: 2017-12-12
Review date: 2021-03-31
Validity date: 2026-03-31
Registration number: S-P-01081

UN CPC 171 - Electrical energy
PCR 2007:08 UN CPC 171 & 173 - Version 4.11 - Electricity, steam and hot water generation and distribution

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Appendix I Agricultural Land Cumulative Impacts Table

Cumulative Agricultural Land appraisal

Based on the "provisional" ALC maps, BMV is estimated to account for about 71.2% of agricultural land in Lincolnshire (c402,900 ha) and 45.2% in Rutland (16,700 ha) (see paragraphs 12.2.16 - 18).

The BMV land within the Order Limits *(which includes the Mitigation and Enhancement Areas which are not to be developed)* would amount to 360 ha (see Table 12.1 in Chapter 12 [**APP-042**], which equates to 0.086% of the estimated 419,600 of BMV in Lincolnshire and Rutland. That is 1/1165th of the BMV land within the two counties.

Question b) ii) seeks a similar estimate based on the area involved with all known solar farms in the area. We have similarly kept the search to Lincolnshire and Rutland.

Site	**Area and BMV Area (Grades 1, 2 and 3a)**
Little Crow	37 ha Subgrade 3a (16% of site).
Tillbridge	1,400 ha, ALC quality not stated in Scoping Report.
Gate Burton	652 ha, of which 74 ha is Subgrade 3a (BMV).
West Burton	200 ha of Grades 1, 2 and 3a across 758 ha site.
Cottam	48 ha Grades 2 and 3a.
Springwell	Scoping shows 497 ha provisionally Grade 2, 1,020 ha undifferentiated Grade 3.
Beacon Fen	LRA ALC identified 7 ha Grade 2, 226 ha Subgrade 3a.
Heckington Fen	58 ha Grade 1, 39 ha Grade 2, 160 ha Grade 3a (49% of Proposed Panel Area).
Temple Oaks	Scoping Report states all land is Subgrade 3b.
Mallard Pass	360 ha Grade 2 and 3a (42% of site).

Excluding Tillbridge where no estimate has been made, these nine schemes collectively estimate including of the order of 1,706 ha of BMV plus a proportion (we will use 40% for the reasons set out in the ES) of the Grade 3 at Springwell estimated at 408 ha.

Collectively these proposals will include circa 2,114 ha of BMV. This would represent 0.5% of the BMV of Lincolnshire and Rutland (2,114/419,600).

Assuming, as would be reasonable, that all proposals will be similar to Mallard Pass and will not adversely affect agricultural land quality, there would be no significant effect on BMV agricultural land.

If fixed equipment and tracks amounts to less than 2% of the total area of each site and represents substations, tracks, solar stations etc (1.7% at Mallard Pass), that would equate to of the order of 42 ha of BMV land. That land will be capable of restoration at decommissioning stage.

The land use of the areas involved is assumed to remain agricultural, with sheep being grazed.

Therefore individually and collectively there will be no significant effect or loss of BMV agricultural land.

Appendix J Swept Path Analysis at B1081 / Ryhall Road Junction

C:\USERS\GFLETCHER\VTP\VTP - CAD\LDA_4990\2002_MALLARD PASS SOLAR FARM\ACAD\1.0.CURRENT\1.0.1.SHEETS\AROWS\4990-2001-T-067-068-P0 - SWEPT PATH ANALYSIS OF 16.5M ARTICULATED VEHICLE & CAR PASSING.DWG

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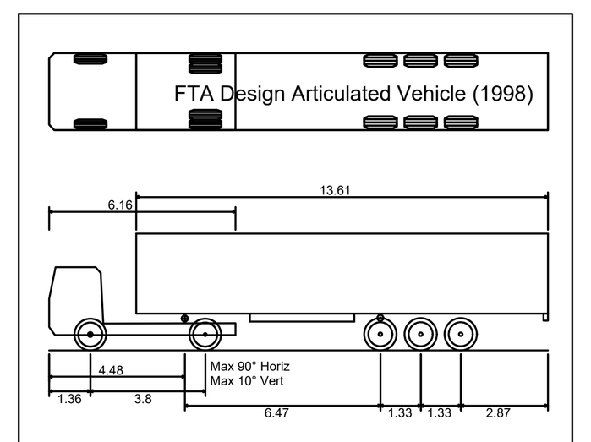
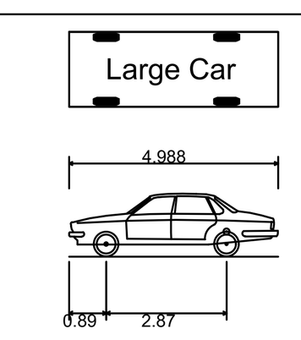
OS Open data / © Natural England / © DEFRA / © DECC / © Historic England / © Environment Agency. Aerial Photography - ESRI, DigitalGlobe, GEOEye, i-cubed, USDA FSA,USGD, AEX, Getmapping, Aerogrid, IGN,IGP,swisstopo, the GIS User Community

LEGEND



FTA Design Articulated Vehicle (1998)	
Overall Length	16.480m
Overall Width	2.550m
Overall Body Height	3.870m
Min Body Ground Clearance	0.515m
Max Track Width	2.470m
Lock to lock time	3.00s
Kerb to Kerb Turning Radius	6.550m



Large Car	
Overall Length	4.988m
Overall Width	1.793m
Overall Body Height	1.502m
Min Body Ground Clearance	0.287m
Track Width	1.700m
Lock to lock time	4.00s
Kerb to Kerb Turning Radius	6.200m

Key Plan

REV.	DESCRIPTION	APP.	DATE
P0	Examination	RP	28/06/23

PROJECT TITLE
MALLARD PASS SOLAR FARM

DRAWING TITLE
Swept path analysis of 16.5m articulated vehicle and large car passing

Infrastructure Planning (Examination Procedure) Rules 2010

PINS REFERENCE NUMBER
EN010127

ISSUED BY	Oxford	T: 01865 887 050	
DATE	28 June 2023	DRAWN	GSF
SCALE@A0	1:250	CHECKED	CR
STATUS	Final	APPROVED	RP

DWG. NO 4990-2001-T-067 **REV : P0**

No dimensions are to be scaled from this drawing.
All dimensions are to be checked on site.
Area measurements for indicative purposes only.

Sources Ordnance Survey

Appendix K MPSF Limited Press Release on Slave Labour

CEO Statement

Following concerns raised about the use of forced labor in the solar industry, Dr Shawn Qu, Chairman, CEO and Founder of Canadian Solar Inc. said in May 2022:

"Canadian Solar strongly condemns the illegal practice of modern slavery or forced labor of any kind. We are confident in the management quality processes that we have in place across our international supply chains. We have undertaken internal investigations and found no evidence of forced labor within our company or our supply chain."

"Canadian Solar continues to take steps to ensure that our supply chain remains free of modern slavery and forced labor. We have published clear policies and processes relating to the prevention of modern slavery and forced labor. We work with national trade bodies to agree and implement strong and accountable supply chain protocols."

A commitment to protect against modern slavery and forced labor

Our culture has always been to support people first and treat everyone with dignity. This extends beyond our company to everyone we interact with in the supply chain, customers and partners.

- Modern slavery, including forced labor, is a crime and a violation of fundamental human rights. Canadian Solar Inc., together with its subsidiary entities ("Canadian Solar"), does not tolerate forced labor or any form of modern slavery, and is committed to ensuring that these illegal practices do not take place anywhere in its business, including across the entire supply chain.

- Canadian Solar expects all its third-party suppliers, contractors and other business partners to act similarly to prevent modern slavery. We do not tolerate any parties directly or indirectly engaging in modern slavery.

- Canadian Solar condemns any form of forced labor. Our suppliers sign on to our supplier code of conduct, which is available on our website. Our assessments shows that there is no modern slavery or forced labor in our supply chain.

- Canadian Solar continues to take steps to ensure that our supply chain remains free of modern slavery and forced labor. We have established implementation measures and verification mechanisms to ensure that our policies and procedures are effective. These policies are publicly available on the governance section of our investor relationship website.

Clear policies

As part of Canadian Solar's commitment to combating modern slavery the company has clear policies and codes of conduct in place including:

- Anti-Modern Slavery Policy – Here
- Labour and Human Rights Policy - Here
- Supplier Code of Conduct - Here
- Code of Business Conduct and Ethics - Here
- Whistleblower Policy - Here

Practical measures to ensure compliance

- All supplier contracts have explicit clauses regarding zero tolerance for forced/child labor.
- Suppliers must sign the Canadian Solar Supplier Code of Conduct which imposes a requirement on all our suppliers to comply with our Anti-Modern Slavery Policy.
- We require our suppliers to ensure their suppliers also agree to our Supplier Code of Conduct. Failure to comply with these codes of conduct will result in the termination of our contract with the supplier.
- Canadian Solar conducts supplier ESG audits and regularly undertakes audits evaluating a range of scored and veto factors. We will immediately terminate our relationship with suppliers who violate veto factors (which includes the potential presence of forced/child labor).
- Canadian Solar is currently working with third party inspection firms that work on supply chain mapping and verify our ability to trace materials and components based on international standards.

Shawn (Xiaohua) Qu

Chairman and CEO

Canadian Solar Inc.

Appendix L IPCC Report (2014) Background Papers

Life Cycle Greenhouse Gas Emissions of Crystalline Silicon Photovoltaic Electricity Generation

Systematic Review and Harmonization

David D. Hsu, Patrick O'Donoughue, Vasilis Fthenakis, Garvin A. Heath, Hyung Chul Kim, Pamala Sawyer, Jun-Ki Choi, and Damon E. Turney

Key words:

global warming
industrial ecology
renewable energy
life cycle assessment (LCA)
meta-analysis
solar

Supporting information is available on the *JIE* Web site

Summary

Published scientific literature contains many studies estimating life cycle greenhouse gas (GHG) emissions of residential and utility-scale solar photovoltaics (PVs). Despite the volume of published work, variability in results hinders generalized conclusions. Most variance between studies can be attributed to differences in methods and assumptions. To clarify the published results for use in decision making and other analyses, we conduct a meta-analysis of existing studies, harmonizing key performance characteristics to produce more comparable and consistently derived results.

Screening 397 life cycle assessments (LCAs) relevant to PVs yielded 13 studies on crystalline silicon (c-Si) that met minimum standards of quality, transparency, and relevance. Prior to harmonization, the median of 42 estimates of life cycle GHG emissions from those 13 LCAs was 57 grams carbon dioxide equivalent per kilowatt-hour (g CO_2-eq/kWh), with an interquartile range (IQR) of 44 to 73. After harmonizing key performance characteristics (irradiation of 1,700 kilowatt-hours per square meter per year (kWh/m^2/yr); system lifetime of 30 years; module efficiency of 13.2% or 14.0%, depending on module type; and a performance ratio of 0.75 or 0.80, depending on installation, the median estimate decreased to 45 and the IQR tightened to 39 to 49. The median estimate and variability were reduced compared to published estimates mainly because of higher average assumptions for irradiation and system lifetime.

For the sample of studies evaluated, harmonization effectively reduced variability, providing a clearer synopsis of the life cycle GHG emissions from c-Si PVs. The literature used in this harmonization neither covers all possible c-Si installations nor represents the distribution of deployed or manufactured c-Si PVs.

Introduction

Background

Life cycle assessment (LCA) is a valuable tool for providing a comprehensive "cradle-to-grave" view of the environmental burdens of a technology. LCA is often used to analyze renewable energy alternatives to conventional energy systems, especially for estimating greenhouse gas (GHG) emissions. LCA tracks not only the GHGs directly emitted during the generation of electricity, but also all of the indirect emissions associated with a particular fuel or technology. The indirect emissions result from upstream processes such as materials extraction, transportation,

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Volume 16, Number S1

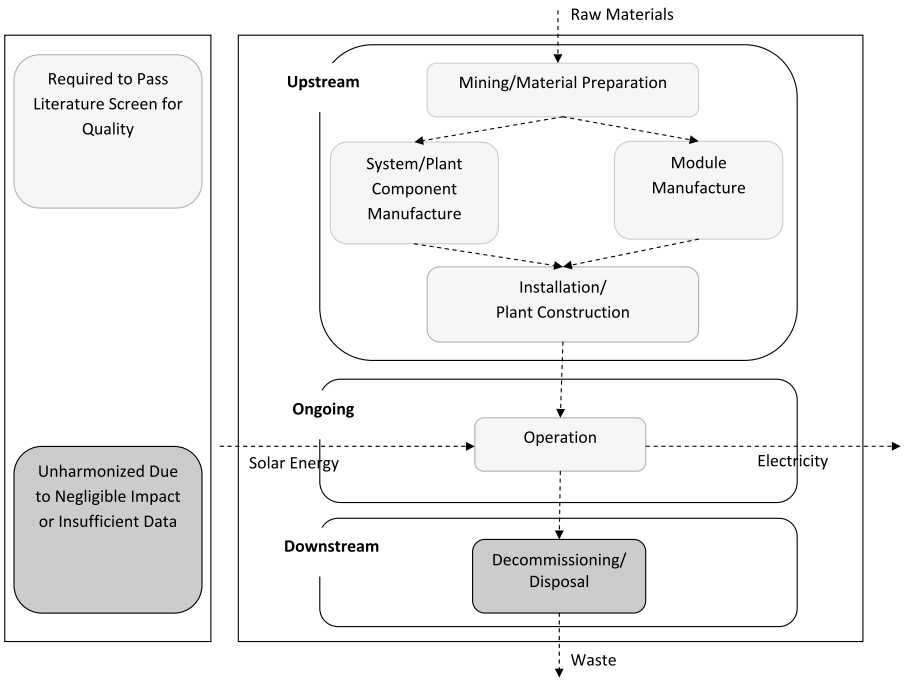

Figure 1 Process flow diagram illustrating the upstream, operational, and downstream life cycle stages of crystalline silicon electricity generating systems and system boundaries used in the harmonization process. Note the downstream impacts were unharmonized due to negligible impact or insufficient data.

and plant construction, as well as downstream processes such as plant decommissioning, recycling of materials, and waste disposal. Figure 1 illustrates the processes included in the system boundary of photovoltaic (PV) LCAs.

Recently the global sales of PV systems have grown rapidly. Most PV systems in the United States (around 77% of market share in 2009) are made from crystalline silicon (U.S. EIA 2011). Crystalline silicon (c-Si) has been used for PV applications for decades and is considered to be the most established PV technology. c-Si PV cells use two types of silicon: monocrystalline and multicrystalline. As the names suggest, monocrystalline silicon (mono-Si) PV cells are made from wafers cut from an ingot of single crystalline silicon and multicrystalline silicon (multi-Si) PV cells are made from wafers containing many different crystals of silicon. Mono-Si cells typically have higher efficiencies and higher manufacturing costs than multi-Si cells (Hegedus and Luque 2003). Although c-Si PV electricity generation is generally accepted as an improvement over fossil fuel technologies with regard to GHG emissions, published scientific literature reports considerable variance in the estimates of life cycle GHG emissions for c-Si PV per unit of electricity generated.

Few attempts have been made to review or clarify the results of PV LCAs. In two review papers, estimated GHG emissions for crystalline silicon PVs have been found to range from less than 50 grams carbon dioxide equivalent per kilowatt-hour (g CO_2-eq/kWh) to 200 g CO_2-eq/kWh (Evans et al. 2009; Pacca et al. 2007).[1] Pacca and colleagues found that GHG emissions and other sustainability factors (energy payback time and net energy ratio) for c-Si and thin-film PVs were sensitive to the amount of input energy for production and manufacture, module efficiency, solar irradiation, and system lifetime (Pacca et al. 2007). The analysis in that study looked at how those parameters would affect the specific result of one LCA. However, Pacca and colleagues did not look at the influence of those parameters on any previously published LCAs. Two other studies have summarized LCA results in the literature (Evans et al. 2009; Sherwani et al. 2010), but none has attempted to standardize parameters in a meta-analysis.

Purpose and Goal

In this article, we take existing LCA studies that report a range of GHG emissions and impose standardized estimates of several key performance characteristics in order to enhance their consistency and improve the ability to collectively consider their results. In this process of "harmonization," we explore the sources of variance and reduce the variability caused by the use of inconsistent performance characteristics. The harmonized results are therefore not meant to improve or correct previous estimates, nor will they reflect any specific c-Si PV project or even all c-Si installations, given gaps in coverage in the available literature. The goal of this article is not to produce a single-point estimate answer that is representative of technology today, but rather the goal is to better understand the variability in results for the sample of quality, up-to-date

LCA studies, and thus better inform decision making and future analyses that rely on such estimates.

Harmonization Methodology

Conceptual Life Cycle Process Description

The life cycle of a c-Si PV system has upstream, operation, and downstream phases (figure 1). The upstream phase starts with the acquisition of raw materials, such as silica sand and iron ore. After these raw materials are acquired, energy is required to process them into other materials, such as crystalline silicon and steel. Energy is then required to manufacture the components for the solar module and the PV system as a whole. The building block of a PV system is a PV cell. A PV cell is a semiconductor device that converts solar energy into electricity. A module is a panel of electrically connected solar PV cells, and in addition to the cells, includes the frame and glass. A PV array consists of several connected modules. The PV system consists of the array plus balance-of-system (BOS) components, which are needed to provide structural support and to deliver electricity to a facility or the grid. The BOS includes wiring, mounting hardware, and inverters. Batteries are normally part of the BOS, but none of the studies in the final harmonization pool nor the final harmonized scenario included battery storage. For an illustration of PV cell, module, and array, see figure S1 in the supporting information available on the journal's Web site. All components are then transported to the site and installed. Prior to operation, most GHGs in the life cycle of c-Si PVs have been emitted (e.g., Frankl et al. 2005). After the solar PV system has been installed, the operation life cycle phase includes activities such as module washing, preventive maintenance (e.g., replacement of inverters), and replacement of any components that break. PV systems have minimal operation and maintenance requirements, and, as such, the GHG emissions from this stage are small (e.g., estimated to be close to zero (Frankl et al. 2005; Uchiyama 1997)]. After the PV system reaches the end of its life, the downstream life cycle phase includes system decommissioning, with parts disposed of or recycled.

Collection of Literature and Initial Screening

The study began with a literature search, amassing 397 journal articles, reports, theses, conference papers, technical reports, trade publications, and presentations relating to LCAs of PVs, including c-Si, thin-film, and other PV technologies. Multiple GHG emission estimates from a single study were possible if alternative PV generation scenarios or technologies were analyzed. Each estimate of life cycle GHG emissions was independently subjected to two rounds of review, consistent with the screening methodology of the umbrella LCA harmonization study conducted by the National Renewable Energy Laboratory (NREL).[2] (Several articles reporting harmonized results for other electricity generation technologies appear in this special issue, including Burkhardt and Heath [2012], Dolan et al. [2012], Kim et al. [2012], Warner and Heath [2012], and Whitaker et al. [2012].) Although an entire reference was not necessarily eliminated if only one of its estimates was screened out, most screening criteria applied to the study as a whole, thereby likely eliminating all estimates in a study.

An initial screen removed studies lacking sufficient documentation necessary for harmonization: conference papers less than or equal to five double-spaced pages; trade journal articles less than or equal to three published pages; and presentations, posters, and conference abstracts. In addition, studies published prior to 1980 were filtered out due to obsolete technology and data inventories. References not available in English were also removed. Although a life cycle, by definition, includes several stages of a product's life from manufacture to end of life, PV LCAs do not need to focus on all life cycle stages because the GHG emissions of solar PVs are heavily weighted toward upstream operation, such as material production and component manufacturing (e.g., Frankl et al. 2005). Thus studies that did not account for downstream life cycle phases were not removed from consideration in this analysis. This initial screen yielded 241 studies, of which 129 studies evaluated c-Si PVs.

Secondary Screening

The second screen consisted of three main criteria:

1. Quality: The study had to employ a currently accepted LCA methodology (e.g., following ISO 14040 series standards [ISO 2006]). The study also had to have at least considered life cycle impacts from the materials extraction and component manufacturing stages, which have been found to be the largest contributors to total GHG emissions for c-Si PV systems (e.g., Frankl et al. 2005).
2. Transparency: The study must have at a minimum described its methods, sources, and values of input data (life cycle inventory [LCI] data, performance characteristics, etc.) and the LCA results.
3. Modern relevance: The evaluated technology must be relevant to current or near future c-Si PVs.

The last criterion eliminated many estimates that used outdated LCI data or made assumptions not applicable to current technologies. For example, Kannan and colleagues (2007) cite a report by Knapp and Jester (2001) as a source of data for the materials and energy required in manufacturing; the Knapp and Jester report describes early production by Siemens in California, which utilized now-obsolete production methods.

The second screen reduced the number of studies to 77, 58 of which assessed c-SI PVs.

Selection of the Harmonization Pool

After gathering the pool of articles that passed the second screen, we selected our group for harmonization on the basis of usability, nonduplication, and consistency of application.

1. Usability: Articles must report life cycle GHG emissions; many articles that passed the second screen, although rigorous studies, did not report life cycle GHG emissions. Also, to limit transcription error, the results had to be reported numerically, not just graphically. Finally, values of several key parameters had to have been reported to be considered for harmonization. If the studies did not report the specific parameter value for each scenario evaluated, but those parameters could be calculated from information in the study using no exogenous assumptions, the scenario estimate was included. We also contacted authors for additional information, and if they provided the information, the scenario estimate was included even if the published version did not include all the necessary parameters. The required parameters were
   a. module conversion efficiency (the percentage of the solar energy converted to direct current [DC] electricity by the module [unitless]),
   b. performance ratio (the ratio of the alternating current [AC] electricity actually produced by the PV system, after accounting for system losses, to the electricity calculated based on the DC-rated module efficiency and irradiation [unitless]),
   c. irradiation (the average energy flux from the sun, in kilowatt-hours per square meter per year [kWh/m^2/yr]),[3] and
   d. system lifetime (the years that a PV system operates, with routine maintenance and repairs, before severe degradation in its ability to produce electricity).
2. Nonduplication: Only original LCA results passed. Many studies cite results from other articles but do not contain any improvements or reinterpretations to the LCA of GHG emissions; we eliminated these articles from our analysis. For example, review papers that did not generate original emissions estimates were excluded. In cases where the same research group published serially on the same technology, when two studies did not report significantly different LCIs or results, we only included the latest or most complete reference; including multiple studies from the same research groups could artificially tighten the distribution.
3. Consistency of application: We eliminated the work of Hayami and colleagues (2005) because that study looked at applications in space and thus was not included in the pool of our studies, which is limited to terrestrial applications. We also excluded the work of Nawaz and Tiwari (2006), as we could not separate the contribution of battery storage from that for the PV system.

The final screening of the harmonization pool resulted in 13 studies and 41 estimates. The studies used in our meta-analysis are listed with the key performance characteristics of each estimate in tables 1 and 2.

Unlike a similar meta-analysis on thin-film LCAs (Kim et al. 2012), the literature used in this study by necessity was not based on real-world manufacturing data. Silicon PV processing technology is fairly mature and much process information is publicly available. Thin-film processes, such as amorphous silicon, cadmium telluride, and copper indium gallium selenide, are less prevalent, and information on those processes is often only

Table 1 Monocrystalline PV LCA studies that passed final screening, with parameter values and characteristics from those studies.

Author	*Year*	*Published GHG emissions (g CO_2-eq/kWh)*	*Solar irradiation (kWh/m^2/yr)*	*Module efficiency (%)*	*Performance ratio*	*System lifetime (years)*	Mounting type *(ground-mounted/ rooftop)*	*Region*
Alsema and de Wild-Scholten	2006	45	1,700	14	0.75	30	Rooftop	Southern Europe
Frankl et al.	2005	68	900	14	0.93	25	Rooftop	Central Europe
		36	1,800	14	0.87	25	Rooftop	Southern Europe
		76	900	14	0.86	25	Rooftop	Central Europe
		41	1,800	14	0.79	25	Rooftop	Southern Europe
		73	900	14	0.92	25	Rooftop	Central Europe
		39	1,800	14	0.86	25	Rooftop	Southern Europe
		69	900	14	0.88	25	Ground-mounted	Central Europe
		37	1,800	14	0.83	25	Ground-mounted	Southern Europe
Jungbluth et al.	2009	64	1,117	14	0.75	30	Rooftop	Switzerland
		69	1,117	14	0.75	30	Rooftop	
Pacca	2003	30	2,143	12.7	1	20	Ground-mounted	Arizona, USA
		100	1,752	12.7	1	20	Ground-mounted	Brazil

Notes: PV = photovoltaic; LCA = life cycle assessment; GHG = greenhouse gas; g CO_2-eq/kWh = grams carbon dioxide equivalent per kilowatt-hour; kWh/m^2/yr = kilowatt-hour per square meter per year.

Table 2 Multicrystalline PV LCA studies that passed final screening, with parameter values and characteristics from those studies.

Author	*Year*	*Published GHG emissions (g CO2e/kWh)*	*Solar irradiation (kWh/m²/yr)*	*Module efficiency (%)*	*Performance ratio*	*System lifetime (years)*	*Mounting type (ground-mounted/ rooftop)*	*Region*
Alsema and de Wild-Scholten	2000	60	1,700	13	0.75	30	Ground-mounted	Western Europe
		30	1,700	15	0.75	30	Ground-mounted	
		20	1,700	17	0.75	30	Ground-mounted	
Alsema	2006	35	1,700	13.2	0.75	30	Ground-mounted	Southern Europe
Frankl et al.	2005	82	900	13	0.93	25	Ground-mounted	Central Europe
		44	1,800	13	0.87	25	Ground-mounted	Southern Europe
		93	900	13	0.86	25	Rooftop	Central Europe
		50	1,800	13	0.79	25	Rooftop	Southern Europe
		88	900	13	0.92	25	Rooftop	Central Europe
		47	1,800	13	0.86	25	Rooftop	Southern Europe
		85	900	13	0.88	25	Rooftop	Central Europe
		46	1,800	13	0.83	25	Rooftop	Southern Europe
Fthenakis and Alsema	2006	36	1,700	13.2	0.75	30	Rooftop	Europe
Hondo	2005	53	1,314	14	0.77	30	Rooftop	Japan
		44	1,314	14	0.77	30	Rooftop	
Jungbluth et al.	2009	57	1,117	13.2	0.75	30	Rooftop	Switzerland
		62	1,117	13.2	0.75	30	Rooftop	
Lenzen et al.	2006	106	2,060	13	0.85	25	Rooftop	Australia
		217	2,060	12	0.8	20	Rooftop	
		53	2,060	14	0.9	30	Rooftop	
Pacca et al.	2006	72	1,359	12.92	0.95	30	Rooftop	Michigan, USA
Pehnt et al.	2002	102	950	13.4	0.85	25	Rooftop	Central Europe
		57	1,700	13.4	0.85	25	Rooftop	North Africa
Pehnt	2006	104	1,100	13.4	0.85	25	Rooftop	Germany
Stoppato	2008	20	1,697	16	0.83	28	Ground-mounted	Turkey
Tripanagnostopoulos et al.	2006	55	1,644	12.4	0.85	30	Rooftop	Greece
		51	1,644	12.4	0.85	30	Rooftop	
		62	1,644	12.4	0.85	30	Rooftop	

Notes: PV = photovoltaic; LCA = life cycle assessment; g CO_2-eq/kWh = grams carbon dioxide equivalent per kilowatt-hour; kWh/m²/yr = kilowatt-hour per square meter per year.

available through the manufacturers. Because the c-Si analysis is not based exclusively on empirical manufacturing data, the results of this article do not represent the current state of c-Si manufacturing.

Harmonization Approach

For the LCA harmonization project as a whole, two levels of harmonization were devised. The more resource-intensive level uses a process similar to one employed by Farrell and colleagues (2006) to harmonize the results of LCAs on ethanol, whereby a subset of the available literature estimates of life cycle GHG emissions was carefully disaggregated to produce a detailed meta-model based on adjusted parameter estimates, realigned system boundaries within each life cycle phase, and a review of all data sources. A less intensive approach harmonizes a larger set of literature estimates of life cycle GHG emissions at a more gross level. This is done, for instance, by adjusting several

influential performance characteristics to consistent estimates and common system boundaries. The latter, less intensive approach was chosen for c-Si PVs, as will be discussed later. The literature available generally did not provide enough detail to apply the more intensive approach.

We created a spreadsheet-based meta-model to harmonize GHG results based on similar assumptions. The harmonization methodology is described in the context of the equation needed to calculate the GHG emissions for solar PVs:

$$GHG = \frac{W}{I \times \eta \times PR \times LT \times A}, \quad (1)$$

where *GHG* is the mass emissions of GHGs weighted by their global warming potential (GWP) per unit of electricity generated (g CO_2-eq/kWh), *W* is the GWP-weighted mass of GHGs emitted over the lifetime of the PV system (g CO_2-eq), *I* is the irradiation (kWh/m^2/yr), η is the lifetime average module efficiency (%), *PR* is the performance ratio, *LT* is the system lifetime (yr), and *A* is the total module area (m^2). This calculation, used in most PV LCA studies, encompasses two characteristics of the technology. The numerator sums all of the GHG emissions from all components and life cycle phases and weights each GHG by GWP, while the denominator calculates the power output over the lifetime of the PV system. In the harmonization process, several factors affecting the denominator are standardized, and *GHG* is recalculated based on these new factors, producing a "harmonized" result.

To harmonize, we first selected standard values for power production parameters in the denominator of equation (1). These factors vary over the literature. Irradiation depends on location. Several studies (Alsema 2000; Alsema and de Wild-Scholten 2006; Pehnt et al. 2002; Fthenakis and Alsema 2006) use an irradiation value of 1,700 kWh/m^2/yr, corresponding to the average irradiation in southern Europe. We report results based on an irradiation of 1,700 kWh/m^2/yr to be aligned with much of the published literature. However, the average irradiation in the United States is higher, at 1,800 kWh/m^2/yr for latitude-tilt, south-facing planes. In addition, the southwest United States accounts for a large portion of the current U.S. PV installations and is a targeted region for concentrating solar power, a technology often compared to silicon PVs. Because of the relevance of the southwest United States, we also report in this article and in the supporting information on the Web the harmonized results for 2,400 kWh/m^2/yr, based on irradiation in Phoenix, Arizona (Moore et al. 2005). The modules are assumed to be at a latitude-tilt for the location, and the effect of the tilt is assumed to be included in the performance ratio. Even though some of the input LCI data in the studies may be specific to a particular region, the studies were harmonized to one location because PV systems manufactured in one location can be installed and operated in another location.

Module efficiencies are always improving, but in this study we chose an initial efficiency of 14.0% for mono-Si and 13.2% for multi-Si based on the Crystal Clear database, a collection of data representing c-Si PVs production technology in Western Europe in 2005–2006 (de Wild-Scholten 2007). The efficiencies degrade over the system lifetime by 0.5% (relative to the initial efficiency) per year (Granata et al. 2010), resulting in an average efficiency over the 30-year lifetime of 13.0% for mono-Si and 12.3% for multi-Si. The lifetime average efficiency was used in harmonization.

The lifetime of a PV system was set at 30 years, as recommended by guidelines from the International Energy Agency (IEA) (Alsema et al. 2009). Many companies provide a 25-year limited warranty for their solar panels, so 30 years is a realistic working lifetime. Additionally, based on observations of solar modules operating longer than 20 years, one study concluded that the modules were unlikely to reach a definite point of failure, but instead were likely to gradually degrade (Skoczek et al. 2009).

Because we are reporting GHG emissions per unit of electricity generated, a harmonization standard was not needed for the system or module area.

For the performance ratio, rooftop and building-integrated systems were assigned a performance ratio of 0.75 and ground-mounted systems were assigned a performance ratio of 0.80; both of these performance ratios were recommended in the IEA guidelines (Alsema et al. 2009). Table 3 lists all harmonization parameters and their selected values.

Because the factors affecting the lifetime power production are multiplied together, each estimate of lifetime electricity production from references passing the screens can be harmonized by multiplying the reported parameter by a multiplicative factor: the ratio of the harmonized parameter standard to the as-reported parameter value. For example, if the irradiation in a study is 1,800 kWh/m^2/yr, the lifetime kilowatt-hours are multiplied by a factor of 0.944 (1,700 divided by 1,800) to achieve the harmonized lifetime electricity production, assuming a location in southern Europe. The harmonized result is calculated by dividing the study's GHG emissions by the harmonized lifetime electricity production. Similarly, the harmonized results in this article can be easily calculated for a different parameter estimate using a different multiplicative factor.

The lifetime GHG emissions, however, cannot be harmonized using an analogous multiplicative approach, as the numerator of equation (1) comprises the sum of GHG emissions (weighted by GWPs) from each life cycle stage. GHG emis-

Table 3 List of parameters that were harmonized in this study and the standard values used in harmonization.

Parameter	*Units*	*Value*
System lifetime	Years	30
Performance ratio		
Ground-mounted	Unitless	0.80
Rooftop	Unitless	0.75
Module efficiency		
Monocrystalline	Initial % (lifetime average %)	14.0 (13.0)
Multicrystalline	Initial % (lifetime average %)	13.2 (12.3)
Solar irradiation	kWh/m^2/yr	1,700

Note: kWh/m^2/yr = kilowatt-hour per square meter per year.

sions from the operation and downstream life cycle stages result mainly from activities (e.g., operation and maintenance, dismantling), and have been shown to be small (e.g., Frankl et al. 2005). In contrast, for the upstream stage, which contributes the majority of GHG emissions, embodied GHG emissions in the materials used in the PV components are most important. Potential factors for harmonization in the numerator include (1) entire life cycle stages such as downstream emissions (recycling, decommissioning), which may potentially be standardized to one value; (2) system boundary, namely the inclusion and exclusion of stages or process within a stage, such as research and development; (3) individual parameters that affect one or more life cycle stages, such as wafer thickness and kerf loss (silicon material lost from sawing).

In our analysis, the numerator was not harmonized due to insufficient reporting across all studies with the exception of one study whose GWPs were harmonized. In that instance, the harmonization step was conducted separate from the main harmonization and reported separately from the general results.

The results were categorized by technology type (mono-Si and multi-Si) and by mounting type. Mounting includes rooftop mounting, commonly used for residential PV systems, and ground-mount, commonly used for utility-scale PV systems. We report descriptive statistics of the reported GHG emissions and the harmonized GHG emissions. The median is used as the main measure of central tendency and interquartile range (IQR) (75th minus 25th percentile values) is used as the main measure of variability. These measures are more robust to outliers than mean, range, and standard deviation. For each harmonization step, changes in the median and IQR are compared with published estimates to describe the impact of the harmonization step.

Results and Discussion

Published and Harmonized Results

The distribution of published life cycle GHG emissions becomes narrower and shifts down after harmonization. Figure 2 compares the original, published estimates of life cycle GHG emissions to the cumulative results of all harmonization steps. Table S1 in the supporting information on the Web lists the published and harmonized results for each of the scenarios in the harmonization pool. Table 4 reports that the median published life cycle GHG emissions estimate for c-Si PVs is 57 g CO_2-eq/kWh; the harmonized median is 45 g CO_2-eq/kWh. The main reason for this decrease in median is because we selected a higher irradiation standard than that used by many of the constituent studies. The studies had a median irradiation of 1,700 kWh/m^2/yr and a mean of 1,481 kWh/m^2/yr, while we harmonized to a value of 1,700 kWh/m^2/yr. If the studies were harmonized to 2,400 kWh/m^2/yr, then the median of the harmonized estimates would be 32 g CO_2-eq/kWh (table 5). See figures S2 and S3 in the supporting information on the Web for additional results based on a harmonized irradiation of 2,400 kWh/m^2/yr.

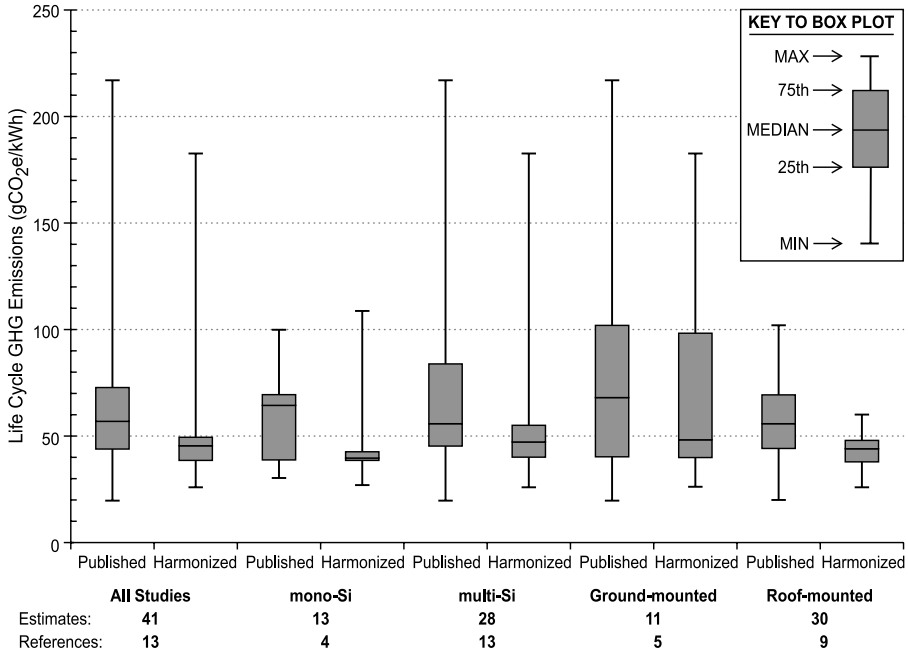

Figure 2 Box plots comparing published and harmonized (irradiation of 1,700 kilowatt-hours per square meter per year [kWh/m^2/yr]) estimates of life cycle greenhouse gas (GHG) emissions from all crystalline silicon (c-Si) LCAs passing screens and grouped according to c-Si PV technology (mono-Si = monocrystalline silicon; multi-Si = multicrystalline silicon) and mounting type. "References" and "Estimates" indicate the number of independent studies and published GHG emission estimates that were harmonized in each step, respectively.

Table 4 Descriptive statistics of published and harmonized (irradiation of 1,700 kWh/m^2/yr) results, including the impact of each harmonization step applied individually for all c-Si LCAs passing screens. (All values except percentages and counts reported in g CO_2-eq/kWh.)

	Published studies	*Harmonized (all steps)*	*Irradiation*	*System lifetime*	*Performance ratio*	*Efficiency*
Mean	63	52	54	54	68	67
Standard deviation	34	29	39	23	38	33
Minimum	19	26	19	18	19	25
25th percentile	44	39	38	37	42	47
Median	57	45	45	53	56	61
75th percentile	73	49	53	64	84	78
Maximum	217	183	263	145	231	212
Interquartile range	29	11	15	27	42	31
Range	198	157	243	126	213	187
Change in mean	—	−18%	−15%	−14%	8%	6%
Change in SD	—	−14%	18%	−31%	14%	−2%
Change in IQR	—	−62%	−48%	−5%	45%	8%
Change in range	—	−21%	23%	−36%	8%	−6%
Count of estimates	41	41	41	41	41	41
Count of references	13	13	13	13	13	13

Notes: kWh/m^2/yr = kilowatt-hour per square meter per year; c-Si = crystalline silicon; LCA = life cycle assessment; g CO_2e/kWh = grams carbon dioxide equivalent per kilowatt-hour; SD = standard deviation; IQR = interquartile range. "References" and "Estimates" indicate the number of independent studies and published greenhouse gas emission estimates that were harmonized in each step, respectively.

The second reason the harmonized median estimate was reduced compared to the published median is change in the assumed system lifetime. The median system lifetime reported by the studies is 25 years, and we harmonized to a value of 30 years, thus amortizing the one-time upstream emissions over a longer period and higher lifetime electricity generation. If the studies were harmonized to a system lifetime of 25 years, then the harmonized median would be 55 g CO_2-eq/kWh, which is close to the median of the published estimates of 57 g CO_2-eq/kWh. The harmonized medians chosen for this article should be a more accurate representation of the studies for the system lifetimes expected for c-Si PV systems in a region with similar irradiation to southern Europe.

Table 5 Descriptive statistics of as-reported and harmonized (irradiation of 2,400 kWh/m^2/yr) results, including the impact of the irradiation harmonization step applied individually for all c-Si LCAs passing screens. (All values except percentages and counts reported in g CO_2-eq/kWh.)

	Published studies	*Harmonized (all steps)*	*Irradiation (2,400 kWh/m^2/yr)*
Mean	63	37	38
Standard deviation	34	20	28
Minimum	19	18	14
25th percentile	44	27	27
Median	57	32	32
75th percentile	73	35	38
Maximum	217	129	186
Interquartile range	29	8	11
Range	198	111	172
Change in mean	—	−42%	−40%
Change in SD	—	−39%	−17%
Change in IQR	—	−73%	−63%
Change in range	—	−44%	−13%
Count of estimates	41	41	41
Count of references	13	13	13

Notes: kWh/m^2/yr = kilowatt-hour per square meter per year; c-Si = crystalline silicon; LCA = life cycle assessment; g CO_2e/kWh = grams carbon dioxide equivalent per kilowatt-hour; SD = standard deviation; IQR = interquartile range. "References" and "Estimates" indicate the number of independent studies and published greenhouse gas emission estimates that were harmonized in each step, respectively.

Table S2 in the supporting information on the Web reports that the median estimate of published GHG emissions is 64 g CO_2-eq/kWh for mono-Si and 56 g CO_2-eq/kWh for multi-Si. The harmonized GHG medians decline to 40 g CO_2-eq/kWh for mono-Si and 47 g CO_2-eq/kWh for multi-Si. The proximity of these harmonized GHG emissions could be expected. Efficiency advantages of mono-Si may be balanced out by a more energy-intensive process. Harmonization appears to clarify that life cycle GHG emissions of these two c-Si technology types are likely similar.

Segregated by mounting type but not by technology group, the median of the published values is 68 g CO_2-eq/kWh for ground-mounted systems and 56 g CO_2-eq/kWh for roof-mounted systems (see table S2 in the supporting information on the Web). Harmonization reduces the median published estimate to 48 g CO_2-eeq/kWh for ground-mounted systems

Harmonization reduced the IQR for the entire group of studies from 44 to 73 g CO_2-eq/kWh to 39 to 49 g CO_2-eq/kWh, a reduction of 62% (table 4). Similar to the shift in the median, the factors most responsible for tightening the IQR are irradiation and system lifetime. Both of these factors reduced most published estimates with high GHG emissions and narrowed the range.

and 44 g CO_2-eq/kWh for roof-mounted systems. The similar harmonized results for ground-mounted and roof-mounted c-Si PVs suggest that the type of mounting is not a large factor in GHG emissions.

Ground-mounted systems have a larger harmonized IQR (40 to 98) compared to rooftop-mounted systems (IQR of 38 to 48). The larger IQR for ground-mounted systems is partly explained by higher estimates from Lenzen and colleagues (2006) than the rest of the harmonized ground-mounted systems. Lenzen and colleagues provide three estimates of GHG emissions for ground-mounted systems. Their harmonized results range from 88 to 182 g CO_2-eq/kWh; their published results range from 53 to 217 g CO_2-eq/kWh. Harmonization affected this study, but not enough to bring the results in line with the other studies on ground-mounted systems. Lenzen and colleagues based their study on solar PV production in Australia, which gets 75% of its electricity from coal (U.S. EIA 2007). This percentage of electricity from coal is much higher than in the United States or Europe. The high GHG emission intensity of grid electricity for PV production in Australia likely accounts for the elevated estimates. This grid electricity would lead to high GHG emissions in any life cycle stage requiring electricity, but particularly in manufacturing. For example, GHG emissions estimates from Lenzen and colleagues (2006) from BOS are quite high compared to the estimates reported in the work of Mason and colleagues (2006). The BOS contribution based on the work of Mason and colleagues (2006) is 27% lower than the estimate from Lenzen and colleagues (2006). Mason and colleagues estimated the GHG emissions using U.S. electricity from BOS for a ground-mounted system; the results of their study have been used in other LCA studies (Alsema 2000; Alsema and de Wild-Scholten 2006; Pacca 2003). However, Lenzen and colleagues do not provide enough disaggregated data to harmonize based on grid electricity or to substitute a BOS estimate from Mason and colleagues.

Table 4 reports published and harmonized descriptive statistics for all of the c-Si estimates, including the impact of the individual harmonization steps. Tables S3 and S4 in the supporting information on the Web present the same statistics broken into multicrystalline and monocrystalline technology

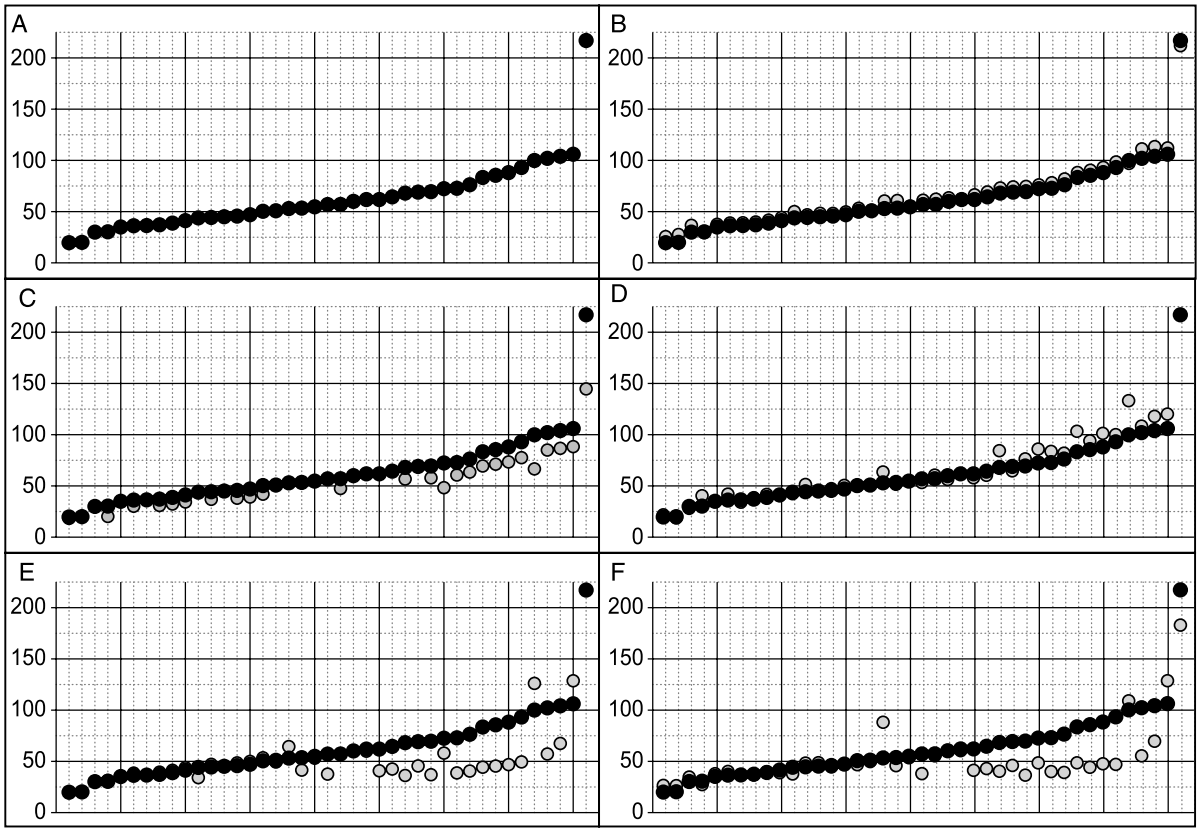

Figure 3 For a harmonized irradiation of 1,700 kilowatt-hours per square meter per year (kWh/m^2/yr), rank-order estimates ($n = 41$) of life cycle greenhouse gas (GHG) emissions (grams carbon dioxide equivalent per kilowatt-hour [g CO_2-eq/kWh]) for crystalline silicon (c-Si) electricity generation, drawn from literature that passed screens for quality, transparency, relevance, and usability. Impact of each harmonization step (gray circles), acting individually, compared to the published estimates (black circles). Frame (A) published; then, harmonized by (B) module efficiency; (C) system lifetime; (D) performance ratio; (E) irradiation; and (F) all steps (acting cumulatively). Numerical data associated with each point are reported in table S1 in the supporting information on the Web.

groups, respectively. Table S2 compares the descriptive statistics for the entire pool of studies and the various mounting and technology subsets.

Figure 3 shows the impact of each harmonization parameter acting independently in frames B through E. Harmonizing the performance ratio, efficiency, and system lifetime minimally reduced the scatter; the largest reductions in variability were caused by harmonizing the system lifetime and irradiation levels. The impact of harmonizing an individual parameter reflects the change in GHG emissions resulting from the shift from the published parameter value to the standard value used for harmonization. Thus the change in results does not represent the general sensitivity of the life cycle GHG emissions to the harmonization parameter.

Several studies experienced large changes as a result of harmonization. Estimates from Frankl and colleagues (2005) and Pehnt and colleagues (2002) represent two of the largest deviations. Table S1 in the supporting information on the web reports the results of each step of the harmonization process applied to each estimate of life cycle GHG emissions considered. Figure S4 in the supporting information on the Web shows the results of each harmonization step applied successively on the pool of estimates considered here. Similar to its impact on many other estimates, much of the deviation between the published and harmonized estimates can be explained by differences in irradiation. Both Frankl and colleagues (2005) and Pehnt and colleagues (2002) had estimates where the irradiation was less than 1,000 kWh/m^2/yr, therefore, when the irradiation was harmonized to 1,700 kWh/m^2/yr, the GHG emission estimate was reduced substantially.

Comparison of Results to Prior Studies

The results of this study align well with the conclusions from the previous study of solar PV LCAs by Pacca and colleagues (2007). In that study, the authors reported that the input energy in production and manufacture had a significant impact on the GHG emissions. The authors also investigated the sensitivity of the net energy ratio to irradiation, module efficiency, and system lifetime. Over the range tested by the authors, they found that the irradiation had a slightly greater effect than system lifetime, and that both irradiation and lifetime had a greater effect than module efficiency. If we take net energy ratio as a proxy for GHG emissions, then our results for the relative impact of the parameters are in line with those of Pacca and colleagues (2007). The comparison also suggests that the energy required in production and manufacture is an important performance characteristic that should be considered for future analyses. Fthenakis and colleagues (2008) showed this effect by presenting different cases for the electricity mixture in silicon production; the study found that moving from a hydropower and natural gas electricity mix to a U.S. electricity mix (with more than 50% from coal) will increase the GHG emissions from c-SI by approximately 50%.

Limitations

Factors Not Harmonized

This meta-analysis primarily focused on standardizing values for input parameters that determine the total lifetime kilowatt-hours of electricity produced by the solar PV system, and no adjustments were made to the lifetime GHG emissions portion of the numerator in equation (1). This numerator is the sum of the GHG emissions from the life cycle stages. The calculation of the numerator can be directly affected in three ways. First, the numerator is affected by the GHG emission contribution from each specific life cycle stage. Second, the GHG emissions from each stage are affected by parameters specific to each stage's processes. For example, the amount of silicon used to produce a PV cell is driven by the wafer yield, which in turn depends on wafer thickness and kerf losses. Third, the calculation of the GHG emissions themselves depend on what GHG species are accounted for and what GWP is used to calculate total GHGs on a CO_2-equivalent basis.

Specific life cycle stage GHG emission contributions are difficult to harmonize. The difficulty is not whether the life cycle stage is considered at all, but rather that GHG emissions related to each stage are not typically disaggregated in LCA studies. For instance, many studies did not account for end-of-life issues (i.e., the downstream life cycle stage). Decommissioning and recycling of the solar modules have not been well studied. In one study, decommissioning and recycling accounted for an average of only 4% of the as-reported GHG emissions (Frankl et al. 2005). Therefore, while not harmonizing to ensure inclusion of the downstream life cycle phase will likely underestimate true life cycle GHG emission from c-Si PV, the degree of underestimation is likely small and will not change the conclusions reached here.

Without knowing the contribution of each life cycle stage, we cannot determine the effect of an individual stage's process parameters. For example, Pehnt and colleagues (2002) report that more than 30% of total GHG emissions are from silicon and wafer production. Adjusting for a parameter that would affect a life cycle stage is not straightforward. One such parameter that would affect the wafer production life cycle stage is wafer thickness. The studies considered in this analysis spanned a range of wafer thicknesses from 200 micrometers (μm) (Stoppato 2008) to 300 μm (Fthenakis and Alsema 2006; Pehnt 2006). Silicon wafers have become thinner over time, with at least one company now producing wafers as thin as 180 μm (LDK 2010). This information is only usable for harmonization if the proportion of the GHG emissions specifically due to silicon and the wafer yield are known. Because most studies did not provide the level of resolution needed to adjust GHG emissions to a common estimate of wafer thickness, wafer thickness was not harmonized. We recognize that it could contribute significantly to the difference in values between studies, given that significant GHG emissions come from the silicon and wafer manufacturing used in the PV module, and suggest this as a useful area of future harmonization research.

Other manufacturing inputs such as silicon type (solar grade or more energy-intensive semiconductor grade) and grid electricity GHG emission intensity may also contribute significantly to variability in estimates of life cycle GHG emissions, but, lacking detailed data, these factors were also not harmonized. The conclusion of the Pacca and colleagues (2007) study that GHG emissions are sensitive to input energy for production and manufacture shows that adjustments to the numerator of equation (1) have potentially significant impacts.

The calculation of GHG emissions is affected by the choice of GWP and the GHGs tracked by the study. In this article we did not harmonize for different GWPs used in studies, with the exception of one study. More recent studies, such as that of Jungbluth and colleagues (2009), used the Intergovernmental Panel on Climate Change (IPCC) 2007 GWPs for methane (CH_4) and nitrous oxide (N_2O) (Forster et al. 2007). However, studies published before 2007 would have used older GWPs. Studies often do not report mass emissions of individual GHGs, so updated GWPs could not be applied. For instance, the IPCC 2001 GWPs (IPCC 2001) are not significantly different from the current IPCC GWPs (23 CH_4 and 296 N_2O compared to 25 and 298, respectively) (Forster et al. 2007). Thus, not harmonizing GWPs would likely have a minimal effect on the overall harmonization results.

Not all GHGs are accounted for in the studies considered here. Most studies did not account for gases with extremely high GWPs, for example, tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), which have 100-year GWPs of 6,500 and 9,200, respectively. Both are used in the manufacture of c-SI solar PV cells. However, based on estimates from the Crystal Clear database (de Wild-Scholten 2007), emissions of perfluorinated compounds are estimated to contribute less than 1 g CO_2-eq/kWh to life cycle GHG emissions from c-Si PVs. Therefore not accounting for these gases should not significantly change the results of this study. Several studies neglected to report CH_4 and N_2O emissions (Alsema 2000; Hondo 2005; Jungbluth et al. 2009). Based on the work of Frankl and colleagues (2005), these GHGs account for 6% of total life cycle GHG emissions. As a result, failure to account for these GHG emissions, while leading to an underestimate of true life cycle GHG emissions, should not change the conclusions of this article.

Project Scope

This study sought to explain and reduce the variability in existing estimates of life cycle GHG emissions of c-Si PVs by identifying critical parameters that varied between studies and by harmonizing them to allow for a consistent comparison of different studies' estimates and a clarified, collective result. As such, the estimates generated during the harmonization process were not designed to reflect plant-specific factors that influence the life cycle GHG emissions of an individual c-Si PV project. The GHG emissions of a specific c-Si PV project depend on many factors and legitimately could differ from the generic estimates generated by the harmonization approach. Furthermore, this work leverages a population of studies that is not necessarily representative of deployed technology or its potential. Although the most relevant, high-quality studies for each technology were selected, the studies reviewed might not represent all cases or even an average case of manufacture, deployment, or use. Just as this study is not backward-looking, it is also not forward-looking and does not project out technological advances.

Recommendations for Future Work

Crystalline silicon PV technology has been commercially available for several decades, and changes in the manufacturing process technology that would dramatically change GHG emissions are not expected. However, opportunities exist to maintain and improve the relevance of LCA studies as the industry changes.

While the silicon type may not dramatically change GHG emissions, the process will likely become more efficient as learning continues. As a result, material utilization efficiency should improve, which would lower GHG emissions. In addition, module efficiency is expected to continue to improve. Module efficiency has a direct effect on the lifetime electricity produced. If module efficiencies improve without significantly increasing the manufacturing energy requirements, GHG emissions per unit electricity generated will drop, and LCA studies should be updated accordingly.

Another notable change in the PV industry is the geographical shift in PV manufacturing. China has become the largest producer of both silicon feedstock and PV modules and is expected to continue increasing its share of production (Navigant Consulting 2009; RTS Corporation 2009). Chinese electricity is highly dependent on coal, and therefore is GHG intensive (Di et al. 2007). At the same time, Chinese manufacturing companies may also install PV to supply part of the electricity needed for manufacturing, thereby decreasing the facility's GHG emissions. One study estimated that substitution of PV electricity for grid electricity in manufacturing multicrystalline modules could decrease GHG emissions by almost 70% (Pacca et al. 2007). None of the studies in this meta-analysis specifically accounted for Chinese manufacturing. LCA studies should start accounting for increased manufacturing in China to better reflect current technology.

Improvements in our knowledge of GHG emissions from end-of-life processes will likely not significantly change current estimates of life cycle GHG emissions from PV systems, but nevertheless, studies on this topic would provide greater confidence that this is the case.

Attributional LCAs are the most prevalent type of LCAs published to date and are therefore relied upon for this retrospective meta-analysis. Attributional LCAs consider the direct emission impacts of a process. In contrast, consequential LCAs consider indirect emission impacts, often the result of economic relationships between the evaluated technology and other technologies. For instance, deployment of an electricity source depending on a variable resource (sunshine) leads to an

increased need for balancing reserves provided by fossil power plants (Gross et al. 2007; Pehnt et al. 2008). Conversely, since PV generates electricity during peak demand periods, increased use of PV should reduce the use of marginal, peaking generators, which are often inefficient natural gas combustion turbines (Denholm et al. 2009; Perez et al. 2008). Additional studies are needed to characterize these indirect impacts.

Lastly, this study is limited to GHG emissions, which is just one of many environmental impacts associated with electricity generation. To fully grasp the environmental burdens of a technology, one must consider the gamut of life cycle impacts, including other airborne emissions, waterborne pollutants, and water consumption.

Conclusion

We screened an extensive body of publicly available estimates of life cycle GHG emission from solar c-Si PV LCAs. After screening 397 total PV references for quality, transparency, relevance, and usability, the range in previous estimates from 13 references relevant to c-Si PV was 20 to 217 g CO_2-eq/kWh. Through conducting a meta-analytical process called harmonization that aligned several input parameters (irradiation of 1,700 kWh/m^2/yr; system lifetime of 30 years; module efficiency of 13.2% or 14.0%, depending on the type of module; and a performance ratio of 0.75 or 0.80, depending on the type of installation), we provide a clearer sense of c-Si PV life cycle GHG emissions in ways intended to be useful for policymakers and analysts. The median published estimate of life cycle GHG emissions for c-Si PVs was 57 g CO_2-eq/kWh with an IQR of 44 to 73 g CO_2-eq/kWh. The harmonization process refined the median GHG result for all c-Si PVs to 45 g CO_2-eq/kWh with an IQR of 39 to 49 g CO_2-eq/kWh (a decrease of 66% from the published IQR). The parameters with the most impact on reducing the spread of the data and reducing the median estimate were system lifetime and irradiation.

Although the life cycle GHG emissions of a specific c-Si project will depend on many factors and can legitimately differ from the estimates generated by the harmonization approach, given the tightness of the distribution of harmonized estimates across two key c-Si technologies (mono- and multicrystalline silicon), the results represent a potentially useful estimate for policymakers. In addition, policymakers can readily adapt the results to obtain a credible estimate of the life cycle GHG emissions for electricity generated by c-Si based on different performance parameters. The distribution of results after meta-analysis show life cycle GHG emissions much lower than the values typical for fossil fuel electricity (Dolan et al. 2012; Whitaker et al. 2012). The results provide a more consistent basis for comparing c-Si with conventional and other renewable electricity technologies. Life cycle analyses of PVs should continue as module and material utilization efficiencies improve, as PV manufacturing is shifted to Asia (potentially increasing life cycle impacts), and as the impacts of introducing variable generation resources onto the grid are better characterized.

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Notes

1. One gram (g) = $10^{=3}$ kilograms (kg, SI) ≈ 0.035 ounces (oz). Carbon dioxide equivalent (CO_2-eq) is a measure for describing the climate-forcing strength of a quantity of greenhouse gases using the functionally equivalent amount of CO_2 as the reference. One kilowatt-hour (kWh) ≈ 3.6×10^6 joules (J, SI) ≈ 3.412×10^3 British thermal units (Btu).
2. Heath and Mann (2012) provide additional background about the screening method used in the NREL harmonization project. Additional data and results of the project are available at http://openei.org/apps/LCA.
3. One square meter (m^2, SI) ≈ 10.76 square feet (ft^2).

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supporting Information S1: This supporting information provides detailed data gathered from each article that passed screening, as well as more explanatory figures of the effects of harmonization. Also included is a full list of the sources that were screened.

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Life Cycle Greenhouse Gas Emissions of Thin-film Photovoltaic Electricity Generation

Systematic Review and Harmonization

Hyung Chul Kim, Vasilis Fthenakis, Jun-Ki Choi, and Damon E. Turney

Keywords:

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carbon footprint
copper indium gallium diselenide
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meta-model

Supporting information is available on the *JIE* Web site

Summary

We present the process and the results of harmonization of greenhouse gas (GHG) emissions during the life cycle of commercial thin-film photovoltaics (PVs), that is, amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). We reviewed 109 studies and harmonized the estimates of GHG emissions by aligning the assumptions, parameters, and system boundaries. During the initial screening we eliminated abstracts, short conference papers, presentations without supporting documentation, and unrelated analyses; 91 studies passed this initial screening. In the primary screening we applied rigorous criteria for completeness of reporting, validity of analysis methods, and modern relevance of the PV system studied. Additionally, we examined whether the product is a commercial one, whether the production line still exists, and whether the study's core data are original or secondary. These screenings produced five studies as the best representations of the carbon footprint of modern thin-film PV technologies. These were harmonized through alignment of efficiency, irradiation, performance ratio, balance of system, and lifetime. The resulting estimates for carbon footprints are 20, 14, and 26 grams carbon dioxide equivalent per kilowatt-hour (g CO_2-eq/kWh), respectively, for a-Si, CdTe, and CIGS, for ground-mount application under southwestern United States (US-SW) irradiation of 2,400 kilowatt-hours per square meter per year (kWh/m^2/yr), a performance ratio of 0.8, and a lifetime of 30 years. Harmonization for the rooftop PV systems with a performance ratio of 0.75 and the same irradiation resulted in carbon footprint estimates of 21, 14, and 27 g CO_2-eq/kWh, respectively, for the three technologies. This screening and harmonization rectifies previous incomplete or outdated assessments and clarifies variations in carbon footprints across studies and amongst thin-film technologies.

Introduction

Thin-film photovoltaic (PV) systems such as amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS) are expanding rapidly due to their low cost, ease of manufacturing, advancing conversion efficiency, and competitive sustainability indicators. These indicators are becoming crucial in assuring the public's acceptance of energy

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technologies since climate change is arguably the most significant threat facing our planet.

Recent studies show that PV technologies have very low environmental and human health impacts compared with those of conventional electricity generation (Fthenakis et al. 2008; Hondo 2005). A broad review of the literature, however, reveals several PV life cycle greenhouse gas (GHG) analyses with widely varying estimates. For example, reported life cycle GHG emissions of thin-film a-Si PV systems range from 11 to 226 grams carbon dioxide equivalent per kilowatt-hour (g CO_2-eq/kWh) of electricity produced (Frankl et al. 2004; Yamada et al. 1995).[1] A significant variation likewise exists in energy payback times for the same type of PV systems, ranging from 1.1 to 6.3 years across studies (Keoleian and Lewis 2003; Uchiyama 1997; Yamada et al. 1995). Such divergence reflects different assumptions on key parameters, for example, solar irradiation, performance ratio, and lifetime. Estimates also deviate because of the different types of installation possible, including ground mount, rooftop, and façade. Most importantly, assessments made from outdated information collected from antiquated PV systems are still cited in the literature and used for guiding policy analyses.

Besides screening out invalid or outdated studies, variability in published life cycle environmental studies can be significantly reduced by aligning system boundaries, parameters, and assumptions (Farrell et al. 2006), a meta-analysis approach called "harmonization" in the present study. By clarifying the central tendency and reducing the uncertainty of estimates, harmonization in this study aims to provide decision makers and interested audiences more accurate information and a balanced perspective on the life cycle GHG emissions from contemporary thin-film PV technologies.

The National Renewable Energy Laboratory (NREL), Columbia University, and Brookhaven National Laboratory (BNL) are engaged in a project for developing balanced comparisons of data and premises across these studies. The project team reviewed life cycle GHG analyses for all PV technologies, harmonizing them by enforcing identical system boundaries and assumptions on major parameters. In the current article we describe the processes for reviewing, screening, and harmonizing the life cycle GHG emissions from thin-film PV technologies (i.e., a-Si, CdTe, and CIGS).

This study reviews and harmonizes only the GHG emissions metric deemed central in making comparisons between different life cycles of electricity generation technologies. In a complete environmental assessment, other metrics such as energy payback time, toxicities, and resource uses need to be concurrently evaluated.

Harmonization Methodology

Life Cycle of Thin-Film Photovoltaics

The PV systems considered by this study comprise the grid-connected PV modules and the balance of system (BOS), which includes cables, inverters, and support structures for the modules. A BOS takes a different form in terms of equipment capacity and materials for ground-mount and rooftop installations, the two most common types. Systems mounted on building façades or with sun-tracking motors were not included in this study because life cycle GHG emissions studies are rare for the necessary BOS equipment. The life cycle of thin-film PV starts with raw materials acquisition, encompasses materials production, film deposition, module production, system assembly, and system operation, and ends with their disposal (figure 1). Also shown in the graph is the life cycle of the BOS, whose life cycle emissions will be added to those of the PV for a complete analysis and will be harmonized based on standard values. Note that the recycling stage of the thin-film PV life cycle was not included in the system boundary of this study, because thin-film installations are relatively new, and end of life has not been described in detail yet. Listed below are detailed processes during the life cycle stages of thin-film PV systems.

1. Upstream processes
   - Raw material acquisition: mining ores, extracting petroleum, and growing woods
   - Materials production: alloying, purification, treatment, mixing, and polymerization
   - Film deposition: chemical vapor deposition and vapor transport deposition
   - Module production: contact formation, encapsulation, wiring, and assembly
   - Module and BOS installation: installing module, inverter, and support structures
2. Operational processes
   - Electricity generation: office use for utility-scale plant
   - Maintenance: scheduled and unscheduled repair and maintenance
3. Downstream processes
   - Decommissioning and disposal: demolition and transportation
   - Recycling: collection, disassembly, shredding, and material separation

Literature Screening

Initial screening

We reviewed 109 studies on the life cycle environmental profile of thin-film PV electricity generation systems published through 2010. The studies were taken from journal articles, conferences, doctoral theses, and technical reports. During our first screening stage we examined the studies' research methods to ascertain consistency with the standard life cycle assessment (LCA) framework. We screened out those studies that did not include the major life cycle stages or upstream material and energy flows. Studies conducted before 1980 were eliminated, as we deemed them outdated, and documents in the form of presentations, posters, and abstracts also were rejected as lacking sufficient documentation. Ninety-one life cycle environmental studies of thin-film PVs passed this first-stage screening

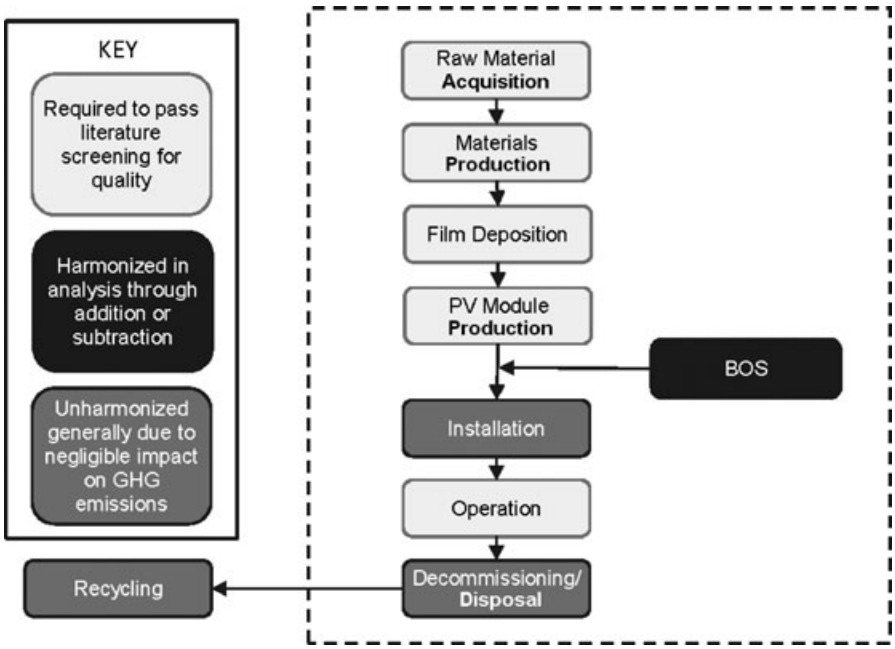

Figure 1 The life cycle of thin-film photovoltaic systems with indications of focused stages. Dotted lines correspond to the system boundary for the harmonization study. BOS = balance of system.

process. Table S1 in the supporting information available on the journal's Web site presents a detailed breakdown of these studies. Most frequently studied is a-Si, at 51 times, followed by CdTe, at 37 times. We attributed this focus to the fact that these technologies have been manufactured and commercialized longer than other thin-film technologies. The total number of technology scenarios at this stage of the harmonization, 124, surpasses the number of studies, 91, because some studies examine multiple thin-film technologies or multiple scenarios for the same technology. Technologies reviewed but unspecified in table S1 in the supporting information on the Web include a-Si/nanocrystalline silicon (nc-Si), gallium arsenide (GaAs), gallium indium phosphide (GaInP), GaInP/GaAs, dye-sensitized cell, and quantum-dot CdSe.

Primary screening

More rigorous quality criteria were set during the second stage of screening for (1) completeness of reporting results and methods, (2) validity of the analysis methods, and (3) relevance to present-day technologies. The screening centered on the stages indicated in figure 1, that is, raw material acquisition, materials production, film deposition, PV module production, and operation. We established detailed subcriteria to facilitate the screening and to ensure consistent, transparent analyses:

1. *Completeness of reporting results and methods*
   Under this criterion we reviewed whether the studies included critical components of LCA, such as functional units, scoping, inventory analyses, and impact analyses. For our current harmonization we eliminated studies that did not examine the GHG emissions. In fact, a wide range of environmental metrics associated with thin-film PV technologies have been evaluated under the LCA framework, including risks, toxic emissions, primary energy, energy-payback times, land use, and water use. We did not consider such analyses, although many are recent and valid, because they did not investigate GHG emissions. The number of studies that included estimates of GHG emissions is 15, 13, and 7 for a-Si, CdTe, and CIGS, respectively (see table S1 in the supporting information on the Web).
2. *Validity of the analysis methods*
   In PV life cycle GHG emissions analyses it is essential to explicitly present the key parameters of analysis, that is, conversion efficiency, performance ratio, irradiation, and lifetime, along with the sources of the information, such as manufacturer, data collector, and age of the data. The guidelines of the International Energy Agency (IEA) (Alsema et al. 2009) detail such requirements for PV LCA.
3. *Relevance to present-day technologies*
   We rejected articles that do not represent modern technologies. To determine modernity we considered module efficiency, manufacturer, scale of production, and module design. In addition, studies based on a hypothetical manufacturing line, future projections, and conceptual modeling were screened out under this constraint. We considered only those investigations based on inventory data from real-world production lines, except those for pilot-scale productions that we deemed relevant. We accepted only the original sources of study results, meaning that we excluded studies that do not contain original investigations.

Table 1 Thin-film amorphous silicon (a-Si) photovoltaic life cycle environmental studies reporting greenhouse gas (GHG) emissions (15 studies, 26 scenarios)

Study	*g CO_2-eq/kWh*	*Solar irradiation (kWh/m^2/yr)*	*Module efficiency (%)*	*PR*	*Lifetime (years)*	*Type*	*Note*
Yamada et al. (1995)	226	1,200	8	0.72	20	G	Production scale = 0.01 GW_p/yr
	125	1,200	13	0.72	20	G	Production scale = 1 GW_p/yr
	101	1,200	16	0.72	20	G	Production scale = 100 GW_p/yr
Uchiyama (1996a)	29	N/A	12.6 (cell)	N/A	30	R	3 kW_p, production scale = 1 GW_p/yr
Uchiyama (1996b)	29	N/A	12.6 (cell)	N/A	30	R	3 kW_p; production scale = 1 GW_p/yr
Uchiyama (1997)	29	N/A	12.6 (cell) 8.6 (system)	N/A	N/A	R	Production scale = 1 GW_p/yr
Martin (1997)	38	N/A	N/A	N/A	30	G	Power plant
Kato et al. (1998)	62	1,427	8	0.81	20	R	3 kW_p; production scale = 10 MW_p/yr
	48	1,427	10	0.81	20	R	3 kW_p; production scale = 30 MW_p/yr
	33	1,427	12	0.81	20	R	3 kW_p; production scale = 100 MW_p/yr
Kato et al. (2001)	58	1,430	8	0.81	20	R	Production scale = 10 MW_p/yr
	44	1,430	10	0.81	20	R	Production scale = 30 MW_p/yr
	30	1,430	12	0.81	20	R	Production scale = 100 MW_p/yr
Meier (2002)	39	1,840	5.7	0.74	30	R	8 kW_p; building-integrated
Frankl et al. (2004)	43.4	1,740	6	0.875	20	R	Retrofit; Rome
	38.6	2,000	6	0.86	20	R	Retrofit; southern Spain
	62.3	1,200	6	0.885	20	R	Retrofit; central Europe
	36.9	1,740	6	0.9	20	R	Building integrated; Rome
	29	1,740	6	0.875	20	R	Integrated skylight roof; Rome
	10.9	1,740	6	0.875	20	R	Integrated skylight roof substituting glass; Rome
Hondo (2005)	26	N/A	8.6	N/A	30	N/A	Future case, 1 GW_p/yr production
Pacca et al. (2006)	34.3	1,359	6.3	0.95	20	R	Building integrated case in Ann Arbor, MI
Pacca et al. (2007)	34.3	1,359	6.3	0.95	20	R	Building integrated case in Ann Arbor, MI
SENSE (2008)	31	1,700	5.5	0.912	20	G	GHG estimate for Rome
Ito et al. (2008)	57	2,017	6.9	0.771	30	G	100 MW_p; Gobi desert
Dominguez-Ramos et al. (2010)	27	1,825	7	0.78	30	G	Installed in Spain

Note: g CO_2-eq/kWh = grams carbon dioxide equivalent per kilowatt-hour; kWh/m^2/yr = kilowatt-hour per square meter per year; PR = performance ratio; N/A = not available; G = ground-mount; R = rooftop; kW_p/yr = kilowatt-peak per year production capacity; MW_p/yr = megawatt-peak per year production capacity; GW_p/yr = gigawatt-peak per year production capacity.

Our chosen metric for GHG emissions (G) is CO_2-equivalent emissions per kilowatt-hour, which is derived as follows:

$$G = \frac{W}{I \times \eta \times PR \times LT \times A},$$

where W = GHG emissions from the life cycle of the PV system (g CO_2-eq), I = irradiation (kilowatt-hours per square meter per year [kWh/m^2/yr]), η = conversion efficiency, PR = performance ratio, LT = lifetime (years), and A = area of the module (m^2).[2] The major emissions considered as GHG emissions in these evaluations include CO_2, methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), and perfluorocarbons (PFCs) converted to CO_2 equivalents using the global warming potential on a 100-year time scale.

Several studies report emissions per square meter of module area or manufacturing capacity. Studies focusing on the environmental impact of processing thin-film PVs often express emissions in this form. Such estimates were converted to emissions per unit of electricity generation (i.e., kilowatt-hours) when sufficient information was given, information such as quantum efficiency and system efficiency, otherwise we discarded such studies. We also excluded studies that report "avoided GHG" emissions that are unconvertible to our functional unit. Finally, we omitted studies reporting normalized global warming indicators rather than presenting GHG emissions. Tables 1 through 3 list the studies that include life cycle GHG emissions. Table S2 in the supporting information on the Web presents those studies with "other" technologies that are not presented here. We note that these estimates are not harmonized and thus are inconsistent with each other in terms of system boundaries and technical parameters, such as performance ratio and lifetime expectancy, solar irradiation, and other assumptions.

Table 2 Thin-film cadmium telluride (CdTe) photovoltaic life cycle environmental studies reporting greenhouse gas (GHG) emissions (13 studies, 24 scenarios)

Study	*g CO_2-eq./kWh*	*Solar irradiation ($kWh/m^2/yr$)*	*Module efficiency (%)*	*PR*	*Lifetime (years)*	*Type*	*Note*
Kato et al. (2001)	51	1,430	10.3	0.81	20	R	Production scale = 10 MW_p/yr
	42	1,430	11.2	0.81	20	R	Production scale = 30 MW_p/yr
	33	1,430	12.4	0.81	20	R	Production scale = 100 MW_p/yr
Alsema et al. (2006)	25	1,700	9	0.75	30	G	
Fthenakis and Kim (2006)	24	1,800	9	0.8	30	G	
Fthenakis and Alsema (2006)	21	1,700	8	0.75	30	R	European production
	25	1,700	9	0.8	30	G	U.S. production
Fthenakis and Kim (2007)	16	1,700	9	0.75	30	R	Installed in Europe
	22	1,800	9	0.75	30	R	Installed in the United States
	17	2,280	9	0.75	30	R	Installed in the United States
	21	2,060	9	0.8	30	G	Installed in the United States
Raugei et al. (2007)	48	1,700	9	0.75	20	R	
Fthenakis et al. (2008)	21	1,700	9	0.8	30	G	UCTE grid mix
	26	1,700	9	0.8	30	G	U.S. grid mix
SENSE (2008)	66	1,200	10	0.912	20	G	
	46	1,700	10	0.912	20	G	
	36	2,200	10	0.912	20	G	
Ito et al. (2008)	47	2,017	9	0.772	30	G	100 MW_p system in Gobi desert
Fthenakis et al. (2009)	19	1,700	10.9	0.8	30	G	U.S. production
	17.7	1,700	10.9	0.8	30	G	German production
	19.5	1,700	10.9	0.8	30	G	German production
Ito et al. (2009)	66.5	2,017	9	0.77	N/A	G	1 GW_p system in Gobi desert
Ito et al. (2010)	50	1,702	N/A	0.78	N/A	G	1 GW_p system in Gobi desert
Dominguez-Ramos et al. (2010)	17	1,825	9	0.78	30	G	German production, installed in Spain

Note: g CO_2-eq/kWh = grams carbon dioxide equivalent per kilowatt-hour; $kWh/m^2/yr$ = kilowatt-hour per square meter per year; PR = performance ratio; UCTE = Union for the Co-ordination of Transmission of Electricity; N/A = not available; G = ground-mount; R = rooftop; MW_p/yr = megawatt-peak per year production capacity; GW_p/yr = gigawatt-peak per year production capacity.

Figure 2 plots the estimates of GHG emissions from the listed studies. The values for CdTe and CIGS show a relatively narrower range than those for a-Si and "other" technologies, which may be partially related to the reporting years for each technology. The analyses of CdTe and CIGS were determined after 2000, while some estimates for a-Si were pre-2000, a fact that is linked to the history of a-Si technology. The median estimate of CdTe's emissions is the lowest, while that of CIGS is the highest. The maximum value for a-Si corresponds to the early estimates by Yamada and colleagues (1995), while the lower one represents the case of building-integrated PVs (BIPVs) with credits for glass substitution in work by Frankl and colleagues (2004). The maximum estimate for emissions in the life cycle of CdTe PVs describes a hypothetical installation case in a remote area (Ito et al. 2009), wherein 75% of the GHG emissions are from constructing the BOS, including the transmission lines, cables, foundation, and array support, that was designed for usage in Japan (earthquake region) (Ito 2010). The lower one corresponds to a rooftop system with 9% efficient modules in Europe (Fthenakis and Kim 2007; Raugei 2010).

Further screening based on criteria 2 and 3 eliminated those technologies that are future projections (e.g., Hondo 2005; Uchiyama 1996a, 1996b, 1997), those based on hypothetical cases (e.g., Ito et al. 2008, 2009, 2010; Kato et al. 1998, 2001), and those lacking detailed parameters (e.g., Martin 1997; Meier 2002). In particular, under criterion 3 we accepted only studies based on life cycle inventory (LCI) data from actual production lines with modern relevance. Table 4 lists those nine studies, encompassing 12 cases, that fall under this classification.

During the final stage of screening, we also considered the following: whether the product is a commercial one, whether the production line still exists, and whether the study references the same data from previous studies (e.g., Fthenakis and Kim 2006; 2007). At this stage we contacted the authors of these articles to verify if the technologies described in the analysis are relevant to modern practices. We confirmed that the a-Si and CdTe lines, detailed in SENSE (2008) and Raugei and colleagues (2007), were phased out after their studies, while the CIGS line is still operating at an expanded scale.

Table 5 lists those studies that passed the final screening, with a brief summary given in the following:

1. Pacca and colleagues (2006). This study assesses the life cycle environmental impact of a hybrid installation of a-Si and multicrystalline Si PV systems on a rooftop in

Table 3 Thin-film copper indium gallium diselenide (CIGS) photovoltaic life cycle environmental studies reporting greenhouse gas (GHG) emissions (7 studies, 14 scenarios)

Study	*g CO_2–eq/kWh*	*Solar irradiation (kWh/m^2/yr)*	*Module efficiency (%)*	*PR (%)*	*Lifetime (years)*	*Type*	*Note*
Frankl et al. (2004)	43.4	1,740	9	0.875	20	R	Retrofit; Rome
	38.6	2,000	9	0.86	20	R	Retrofit; southern Spain
	62.3	1,200	9	0.885	20	R	Retrofit; central Europe
	36.9	1,740	9	0.9	20	R	Building integrated; Rome
	32	1,740	9	0.875	20	R	Integrated skylight roof; Rome
	20.5	1,740	9	0.875	20	R	Integrated skylight roof substituting glass; Rome
Raugei et al. (2007)	95	1,700	11	0.75	20	R	
SENSE (2008)	61	1,200	11.5	0.912	20	G	
	43	1,700	11.5	0.912	20	G	
	33	2,200	11.5	0.912	20	G	
Ito et al. (2008)	38.5	2,017	11	0.776	30	G	100 MW_p system in Gobi desert
Ito et al. (2009)	58.8	2,017	10.1	0.77	N/A	G	1 GW_p system in Gobi desert
Ito et al. (2010)	44	1,702	N/A	0.78	N/A	G	1 GW_p system in Gobi desert
Dominguez-Ramos et al. (2010)	33	1,825	10	0.78	30	G	German production, installed in Spain

Note: g CO_2-eq/kWh = grams carbon dioxide equivalent per kilowatt-hour; kWh/m^2/yr = kilowatt-hour per square meter per year; PR = performance ratio; N/A = not available; G = ground-mount; R = rooftop; MW_p/yr = megawatt-peak per year production capacity; GW_p/yr = gigawatt-peak per year production capacity.

Ann Arbor, Michigan, USA. The materials and energy data for the manufacturing stage of a-Si PV were provided by United Solar, whereas those of multicrystalline Si PV were from the literature. The installed a-Si PV array facing the south with a 12° tilt angle receives a solar irradiation of 1,359 kWh/m^2/yr in this location. The life cycle CO_2 emissions from the a-Si PV module with 6.3% efficiency corresponded to 34.3 g/kWh over a 20-year

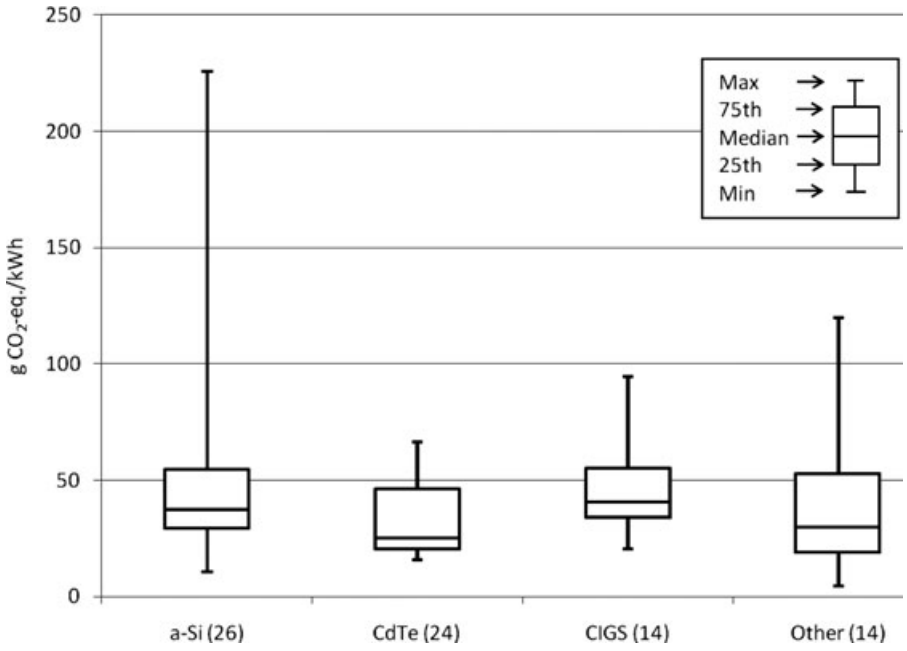

Figure 2 Box plot of GHG emissions reported in thin-film PV life cycle environmental studies published from 1995 to 2010. Figures in parentheses indicate the number of scenarios.

Table 4 Life cycle environmental studies based on actual production data

Technology	*Study*	*Manufacturer*	*Data year*	*Production scale for data*
a-Si	Pacca et al. (2006)	United Solar	2004	Commercial, 28 MW_p/yr
a-Si	Pacca et al. (2007)	United Solar	2004	Commercial, 28 MW_p/yr
a-Si	SENSE (2008)	Free Energy Europe	2003–2006	Pilot
CdTe	Fthenakis and Kim (2006)	First Solar	2005	Commercial, 25 MW_p/yr
CdTe	Fthenakis and Alsema (2006)	First Solar	2005	Commercial, 25 MW_p/yr
CdTe	Fthenakis and Kim (2007)	First Solar	2005	Commercial, 25 MW_p/yr
CdTe	Fthenakis et al. (2008)	First Solar	2005	Commercial, 25 MW_p/yr
CdTe	Fthenakis et al. (2009)	First Solar	2008	Commercial, 716 MW_p/yr
CdTe	SENSE (2008)	Antec Solar	2003–2006	Pilot
CdTe	Raugei et al. (2007)	Antec Solar	2004	Pilot
CIGS	Raugei et al. (2007)	Würth Solar	2004	Pilot
CIGS	SENSE (2008)	Würth Solar	2003–2006	Commercial, 15 MW_p/yr

Note: a-Si = amorphous silicon; CdTe = cadmium telluride; CIGS = copper indium gallium diselenide; MW_p/yr = megawatt-peak per year production capacity.

lifetime. Note that this estimate takes into account an assumed degradation of module efficiency of 1.1% per year.

2. Raugei and colleagues (2007). This study investigated the environmental performance of thin-film PVs, including CIGS, under a European research project on the acceptability of advanced PV technologies (PVACCEPT). Data for CIGS were collected from a prototype batch line at Würth Solar, Germany (Raugei et al. 2007). It is noted that the GHG estimates of this study, 95 g CO_2-eq/kWh under solar irradiation of 1,700 kWh/m^2/yr, do not represent standard production; according to the author the electricity demand was probably overstated (Raugei 2010). Also, the higher glass demand (25 kilograms [kg]/m^2) reflected a very high percentage of breakage in the prototype line (Raugei 2010; Raugei et al. 2007).[3]
3. SENSE (2008). A European Commission (EC) project, Sustainability Evaluation of Solar Energy Systems (SENSE), included an investigation of life cycle GHG emissions for a commercial standard line of CIGS at Würth Solar, Germany, with a 15 megawatt-peak production capacity per year (MW_p/yr)[4] (SENSE 2008). Under this project, a group of manufacturers and scientists assessed the life cycle environmental impact of thin-film PV technologies (i.e., a-Si, CIGS, and CdTe). Representing a standard line, and with a slightly higher conversion efficiency (11.5% versus 11%), the life cycle GHG estimate of CIGS PVs in this study, 43 g CO_2-eq/kWh under solar irradiation of 1,700 kWh/m^2/yr, is less than half of that by Raugei and colleagues (2007). However, since the current line produces 30 MW_p/yr, the GHG emissions presented therein likely are not up-to-date (Held 2010).

Table 5 As-published and harmonized life cycle greenhouse gas (GHG) emissions (grams carbon dioxide equivalent per kilowatt-hour [g CO_2-eq/kWh]) based on solar irradiation of 2,400 kilowatt-hours per square meter per year (kWh/m^2/yr)

				Harmonized									
				Module									
		As published					*PR*	*PR*		*All*[c]	*All*	*System*	
Technology	*Study*	*Module*	*System*	η	*LT*	*I*	*(G)*	*(R)*	*Other*[b]	*(G)*	*(R)*	G	R
a-Si	Pacca et al. (2006)	36	N/A	36	24	20	43	46	31	14	15	20	21
CdTe	Fthenakis et al. (2008)	19	26	16	19	13	19	20	21	12	13	16	17
CdTe	Fthenakis et al. (2009)	12[a]	19[a]	12	12	9	12	13	13	9	10	14	14
CIGS	Raugei et al. (2007)	70	95	67	47	50	66	70	76	32	34	36	38
CIGS	SENSE (2008)	37	43	37	25	26	42	45	40	22	23	26	27

[a]The average of three estimates.
[b]Accounting for non-CO_2 GHG emissions, using current global warming potential (GWP) values (Forster et al. 2007) and assuming 0.5% per year degradation of module efficiency (Alsema et al. 2009).
[c]Harmonized by all the parameters previously listed, that is, η, LT, I, PR, and other.
Note: a-Si = amorphous silicon; CdTe = cadmium telluride; CIGS = copper indium gallium diselenide; η = module efficiency; LT = lifetime; I = solar irradiation; PR = performance ratio; G = ground-mount; R = rooftop.

4. Fthenakis and colleagues (2008). This study investigated the life cycle emissions of major commercial PV systems, multicrystalline Si, monocrystalline Si, ribbon Si, and CdTe, based on industry data from 2004 to 2006. For CdTe, the data were collected from the First Solar plant in Perrysburg, Ohio, USA, describing the operational conditions in 2005. The production capacity of the plant was 25 MW_p/yr and the module efficiency was 9% at the time of this study. The GHG estimates were 26 and 21 g CO_2-eq/kWh under solar irradiation of 1,700 kWh/m^2/yr with a ground-mount installation, corresponding to the actual U.S. and hypothetical European production scenarios.
5. Fthenakis and colleagues (2009). This study is based on data collected from First Solar's plant in Perrysburg, Ohio, USA, and from the plant in Frankfurt-Oder, Germany, in 2008; it is an update of the Fthenakis and colleagues (2008) study that described the operational conditions in 2005. Reduced energy consumption in the production line resulted in lower GHG estimates of 18 to 20 g CO_2-eq/kWh from the previous 26 g CO_2-eq/kWh under the solar irradiation of 1,700 kWh/m^2/yr. The improvement in efficiency of PV modules over this time also was significant (i.e., from 9% to 10.9%), which partially contributes to the reduction in GHG emissions between the two investigations (Fthenakis et al. 2009).

Harmonization Approach

For the LCA harmonization project[5] as a whole, two levels of harmonization were devised. The more intensive and in-depth level envisions a process similar to that employed by Farrell and colleagues (2006) to harmonize the LCA results on ethanol, whereby analyses of life cycle GHG emissions are carefully disaggregated to produce a detailed meta-model enabling adjustment of parameters, realignment of system boundaries within and across life cycle phases, and review of all data sources for adequacy (Farrell et al. 2006). A less-intensive approach, which is adequate for a larger set of literature, could harmonize GHG emissions estimates at a more gross level for several influential performance characteristics and to common system boundaries. The former was chosen for harmonizing life cycle GHG emissions of thin-film PV technologies of which the qualified population is relatively small, and thus suitable for intensive analysis.

During the harmonization stage, we adjusted key parameters of the life cycle impact, such as module efficiency, lifetime, performance ratio, solar irradiation, and efficiency degradation. In addition, assumptions on the system's boundary were examined (e.g., types of BOS and frame). To obtain the life cycle GHG emissions of a complete system, as indicated in figure 1, the BOS components must be considered together with the PV module system, including inverters, cables, and mounting structures for ground-mounted BOS. The GHG emissions from rooftop BOS used in this harmonization were adapted from the latest information from the Crystal Clear project (de Wild-Scholten 2009), that is, 5 g CO_2-eq/kWh under solar irradiation of 1,700 kWh/m^2/yr, with 14% module efficiency and a performance ratio of 0.75. The same information for the ground-mounted BOS is taken from the analysis of the Tucson Electric Power (TEP) power plant in Springerville, Arizona, USA, where the GHG emissions correspond to 5.5 g CO_2-eq/kWh with 12.2% module efficiency under an average solar irradiation of 1,800 kWh/m^2/yr and a performance ratio of 0.8 (Mason et al. 2006). Emissions from the structural part of the BOS are adjusted according to the conversion efficiency of PVs because a high-efficiency module requires less structural material to produce a unit kilowatt-hour, in contrast to emissions from the inverter portion of the BOS, which are unchanged. Note that for harmonization we selected the frameless design of thin-film CdTe and CIGS PVs. Unlike crystalline Si modules that require an aluminum frame for structural stability, typically ~3 kg/m^2 of panel, CdTe and CIGS thin-film modules with a double-glass design do not necessarily require a frame. The current triple-junction a-Si module deposited on a stainless-steel substrate, manufactured by United Solar, uses an aluminum frame with a very thin profile, specifically, 15 g of anodized extruded aluminum per square meter of module, except for building-integrated applications (Pacca et al. 2006).

Below we list the reference parameters selected; they are the figures most accepted as reflecting current PV technologies. For module efficiency, the latest values in the reviewed literature are used.

1. Solar irradiation
   - Southwestern Unites States (Phoenix, Arizona): 2,400 kWh/m^2/yr
   - Southern Europe: 1,700 kWh/m^2/yr
2. Module efficiency
   - a-Si: 6.3%
   - CdTe: 10.9%
   - CIGS: 11.5%
3. Degradation in efficiency: 0.5% per year (Alsema et al. 2009)
4. Performance ratio
   - Ground mount: 0.8
   - Rooftop: 0.75
5. Lifetime: 30 years
6. BOS data source
   - Ground mount: Mason and colleagues (2006)
   - Rooftop: de Wild-Scholten (2009)
7. Global warming potential (GWP)
   - Account for non-CO_2 GHG emissions (CH_4, N_2O, CFCs, PFCs, and so on)
   - Intergovernmental Panel on Climate Change (IPCC) 2007 values (Forster et al. 2007)

Results

Table 5 shows the harmonized estimates based on the irradiation of the U.S. Southwest, where construction of

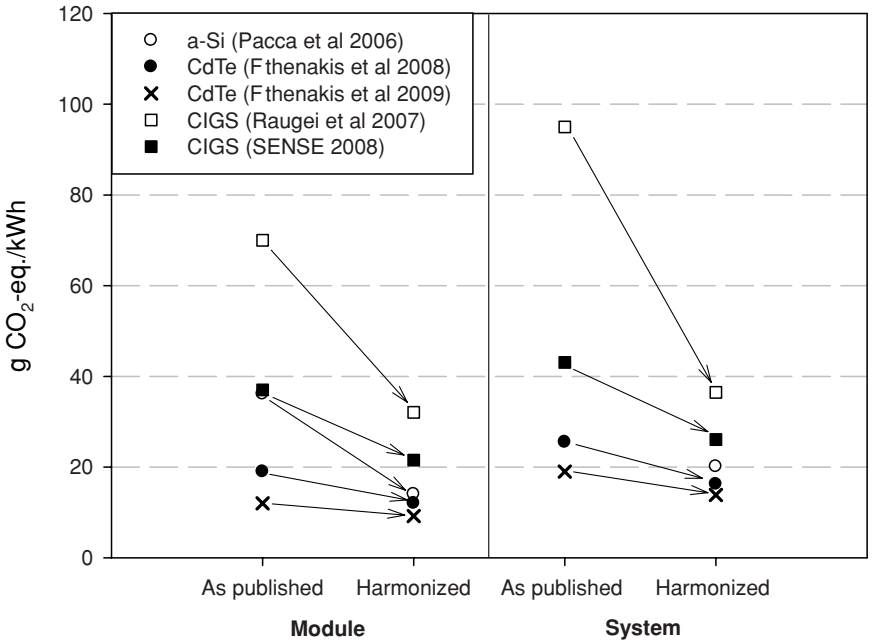

Figure 3 Harmonization of GHG emission estimates that passed the final screening for ground-mount installation without an aluminum frame, based on solar irradiation of 2,400 kilowatt-hours per square meter per year (kWh/m^2/yr). Module efficiency: CdTe, –10.9%; a-Si, –6.3%; CIGS, –11.5%; lifetime = 30 years and performance ratio = 0.8. The arrows show the effect of harmonization on individual technology scenarios.

major ground-mount PV power plants is in progress or on the way, which is 2,400 kWh/m^2/yr. The cases with irradiation of 1,700 kWh/m^2/yr can be found in table S3 in the supporting information on the Web. Harmonized estimates for each parameter as well as the combined harmonized values are presented. Figure 3 illustrates the harmonized and preharmonized data for the studies of ground-mount installation under 2,400 kWh/m^2/yr. First, our harmonization greatly lowers the overall ranges of GHG estimates for the life cycle of thin-film PVs (e.g., from 12–70 to 9–32 g CO_2-eq/kWh for modules and from 19–95 to 14–36 g CO_2-eq/kWh for total ground-mount PV systems). The harmonization of rooftop BOS produced a similar range of 10 to 34 g CO_2-eq/kWh for modules and 14 to 38 g CO_2-eq/kWh for the total system. Note that if we exclude the earlier estimates of CdTe (Fthenakis et al. 2008) and CIGS (Raugei et al. 2007) from figure 2, the current harmonized estimates for the three thin-film PV systems are even lower, at 20, 14, and 26 g CO_2-eq/kWh for a-Si, CdTe, and CIGS, respectively, for ground-mount applications under the reference conditions. The most significant decrease during harmonization (from 95 to 36 g CO_2-eq/kWh) was that for the total system estimate of CIGS based on a 20-year lifetime and with an aluminum frame (Raugei et al. 2007). Simply extending the module's lifetime from 20 to 30 years reduces the module-only estimate of both a-Si (Pacca et al. 2006) and CIGS (SENSE 2008) by 30%. By additionally adjusting the degradation in efficiency from 1.1% to 0.5% per year, and increasing solar irradiation from 1,359 kWh/m^2/yr in the original study to 1,700 kWh/m^2/yr, the former estimate drops by ~40%, although the performance ratio decreased from 0.95 to 0.75. The harmonization results based on an irradiation of 1,700 kWh/m^2/yr is illustrated in figure S1 in the supporting information on the Web.

Discussion

Both the as-published and harmonized life cycle GHG emissions results indicate that the carbon footprint of thin-film PV technologies decrease significantly as the production capacity increases, reflecting technological advances in process and device designs. For example, between 2005 and 2008, First Solar's annual production capacity of CdTe PVs jumped from 25 to 716 MW_p, and during the same period the module efficiency of CdTe PVs increased from 9% to 10.9% and the GHG estimate fell by ~30% (Fthenakis et al. 2008, 2009). As of the first quarter of 2011, First Solar's CdTe PVs have a conversion efficiency of 11.7% (First Solar 2011). Scaling up a CIGS PV prototype to a 15 MW_p commercial line for Würth Solar also corresponds to a significant (i.e., ~50%) reduction in GHG emissions (Raugei et al. 2007; SENSE 2008). We also expect further reductions in GHG estimates for a-Si, as the capacity of United Solar has been expanding rapidly (178 MW_p/yr as of 2009) and the data now available may be outdated (Energy Business Review 2010). Relatively small improvements in efficiency also occurred in a-Si PVs; the current efficiency of a-Si PV modules is 6.7%, compared with the 6.3% used in the most recent study we report herein.

In the harmonization process we allowed for variability in manufacturing locations and detailed system boundaries. The geographic location of the PV module plant affects the upstream grid mix, and consequently the GHG emissions factors per kilowatt-hour of electricity used for producing PVs. The estimates of Raugei and colleagues (2007) and SENSE (2008) assume the Union for the Co-ordination of Transmission of Electricity (UCTE) grid mix for electricity consumption, while those of Fthenakis and colleagues (2008), Pacca and colleagues (2006), and the U.S. case of Fthenakis and colleagues (2009) assume the average U.S. grid mix. The German cases of Fthenakis and colleagues (2009) use the German grid mix. The UCTE grid mix has a lower GHG emissions factor (510 g CO_2-eq/kWh) than those for the United States (760 g CO_2-eq/kWh) and Germany (660 g CO_2-eq/kWh) (Frischknecht et al. 2007). These cannot be easily harmonized, as a detailed breakdown of energy use during the manufacturing stage was not provided in some studies. Harmonizing for a specific geographic location may be unnecessary and unrealistic as thin-film PV technologies are deemed difficult to replicate. Although the effect may be minor, the database for the same grid mix often varies across studies. For example, Raugei and colleagues (2007) employed the ETH-ESU database, while SENSE (2008) used the Gabi database for the same UCTE grid mix.

We note that harmonizing system boundaries of the manufacturing and end-of-life stages was not attempted because they were not clearly defined across studies or a detailed breakdown of these stages was not available. For example, the U.S. case discussed by Fthenakis and colleagues (2009) includes research and development (R&D)-related electricity uses in the system's boundaries, while other studies do not include it or do not specify if it is included. The recycling stage was included within the system boundary of SENSE (2008) analysis for CIGS and the German cases in the work of Fthenakis and colleagues (2009) for CdTe, while it was not included in the rest of the studies passing the final screening. However, harmonizing the end-of-life stage may affect the GHG emissions estimate only slightly; according to the SENSE (2008) analysis, this stage accounts for only 2.6% of the life cycle GHG emissions from CIGS PVs.

Conclusion

We reviewed 109 life cycle environmental studies on thin-film PVs. After rigorously screening the completeness, validity, and data quality of each study, we selected five studies as representative of the carbon footprint of modern thin-film PV technologies. We harmonized the major parameters of PV life cycle GHG emissions, including solar irradiation, performance ratio, and lifetime. The resulting latest estimates of GHG emissions are 20, 14, and 26 g CO_2-eq/kWh for a-Si, CdTe, and CIGS, respectively, for ground-mount application under solar irradiation of 2,400 kWh/m^2/yr, a performance ratio of 0.8, and a lifetime of 30 years. For the same technologies, the harmonized latest estimates for rooftop application under solar irradiation of 2,400 kWh/m^2/yr and a performance ratio of 0.75 correspond to 21, 14, and 27 g CO_2-eq/kWh. The screening and harmonizing described in this article significantly reduced the uncertainty of estimates of GHG emissions for thin-film PVs. In addition, harmonization allowed us to appraise the real variations of carbon footprint across device technologies, production scales, and the age of the data in thin-film PV life cycle GHG emissions analyses. In fact, the ranges of the estimates of GHGs from thin-film PVs were drastically narrowed through harmonization, that is, to ~40% and ~50%, respectively, for modules and total system rooftop application. Overall, this harmonization reduced the uncertainty and ambiguity of the reported values of the carbon footprint of these technologies, and contributed to rectifying previous incomplete or outdated assessments.

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Notes

1. Carbon dioxide equivalent (CO_2-eq) is a measure describing the climate-forcing strength of a quantity of greenhouse gases using the functionally equivalent amount of CO_2 as the reference. One gram (g) = 10^{-3} kilograms (kg, SI) ≈ 0.035 ounces (oz); one kilowatt-hour (kWh) ≈ 3.6×10^6 joules (J, SI) ≈ 3.412×10^3 British thermal units (BTU).
2. One square meter (m^2, SI) ≈ 10.76 square feet (ft^2).
3. One kilogram (kg, SI) ≈ 2.204 pounds (lb).
4. One megawatt (MW) = 10^6 watts (W, SI) = 1 megajoule/second (MJ/s) ≈ 56.91×10^3 British thermal units (BTU/minute).
5. Additional data and results of the project are available at http://openei.org/apps/LCA.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supporting Information S1: This supporting information contains supplementary tables and figures providing the number of studies/scenarios reporting GHG emissions based on thin-film PV types (Table S1), detailed characterization of life cycle environmental studies for "other" PV types (Table S2), and the harmonization result with a solar irradiation of 1,700 kWh/m^2/yr (Table S3 and figure S1).

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